A Data Assimilation Approach to Solving the Coupled Ring Current Radiation Belt System

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LWS Rad Belt Model workshop, October 2004

Model Types

Purely Empirical

- exactly represent average of large data sets
- limited consistency with physical equations
- difficult/impossible to extrapolate

Data Assimilation

- use all available observations + physical knowledge to constrain the model dynamics
- fidelity to physical equations and observations
- can provide cognitive synthesis + physical understanding + practical application

Physics-Based Models

- limited ability to incorporate or match observations
- detailed physics and theory

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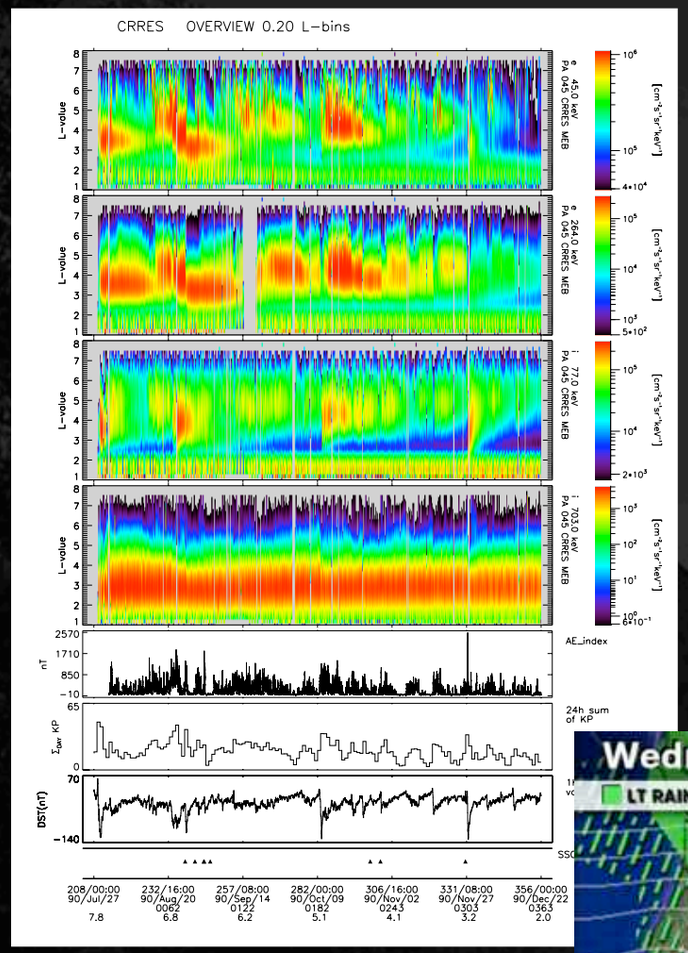
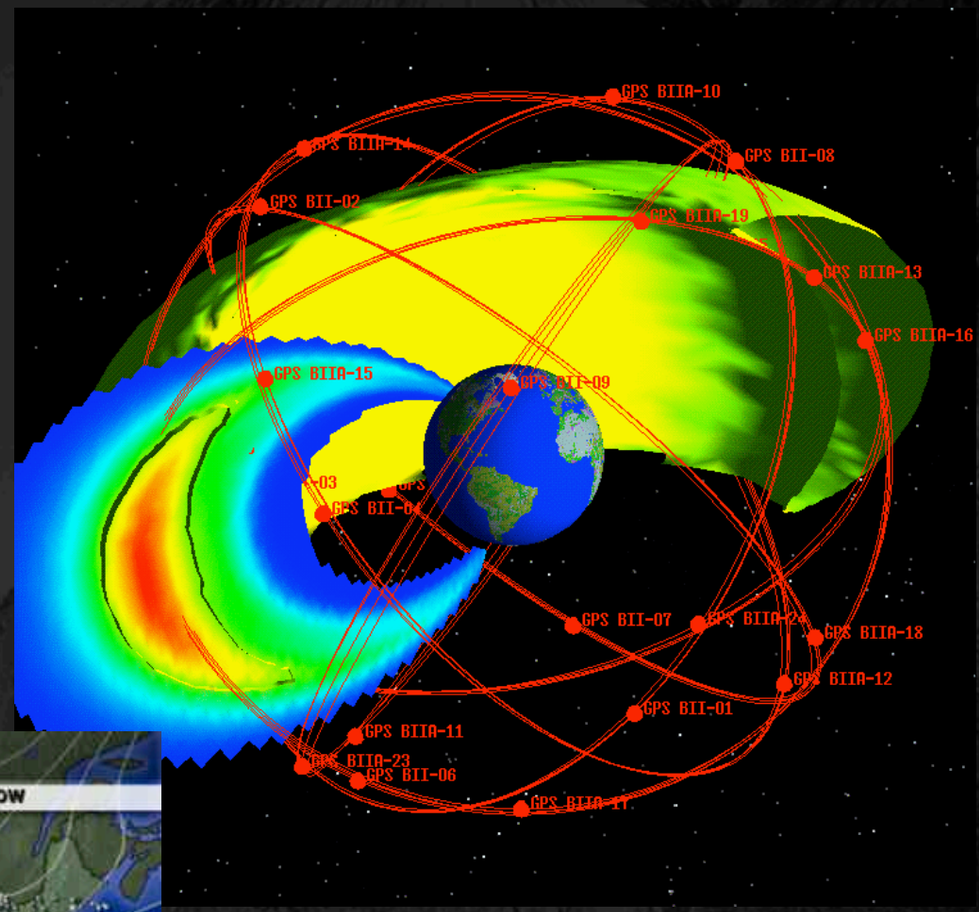
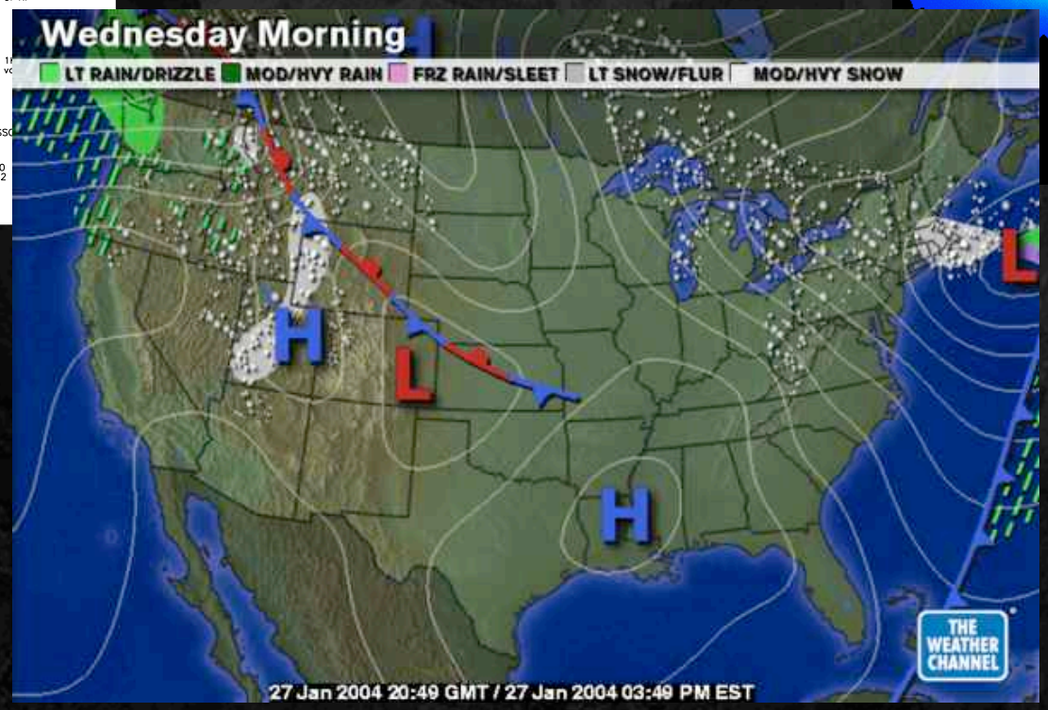
Cognitive Synthesis

Multi-Dimensional Data



30+ Satellites





Cognitive Synthesis

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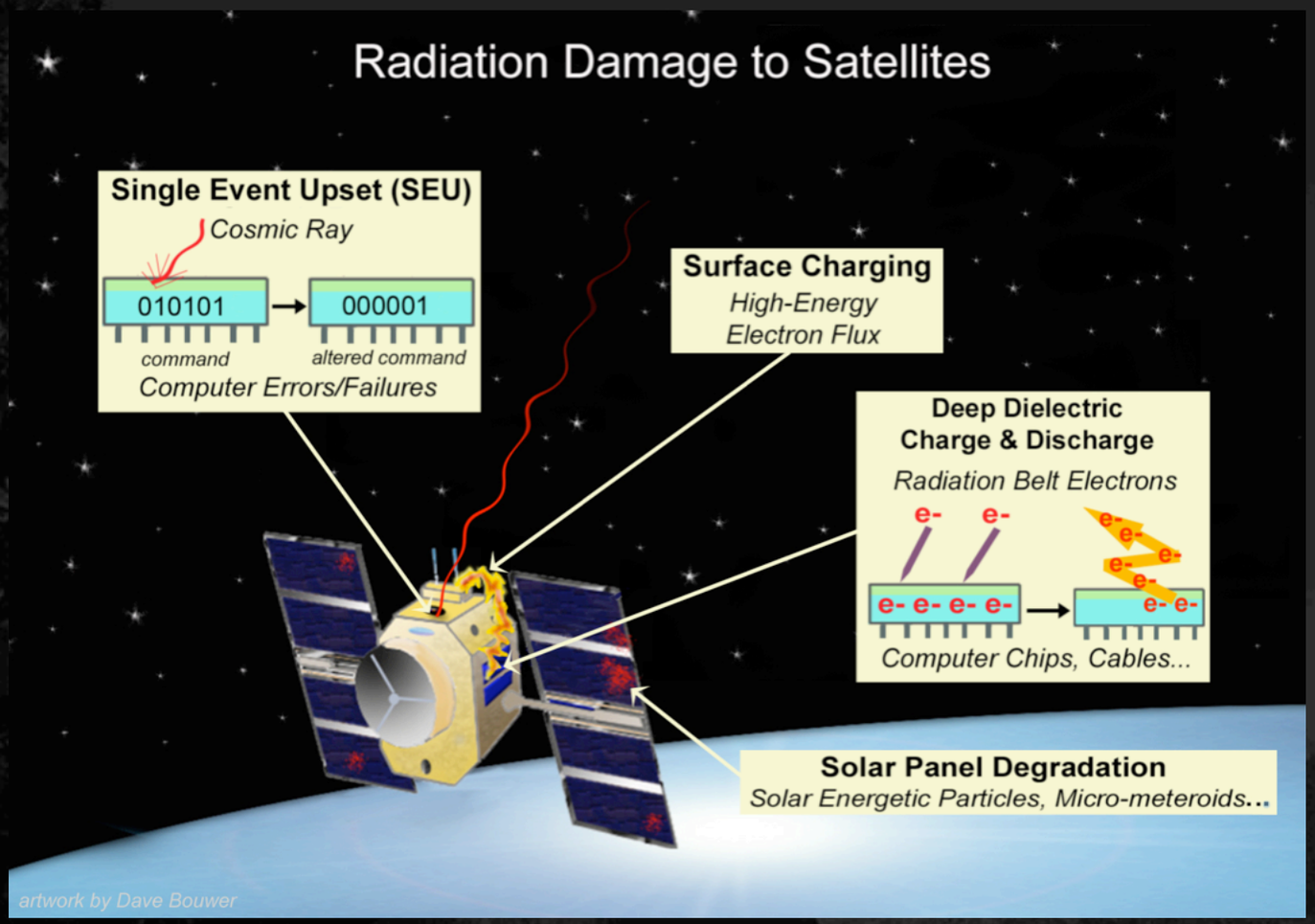
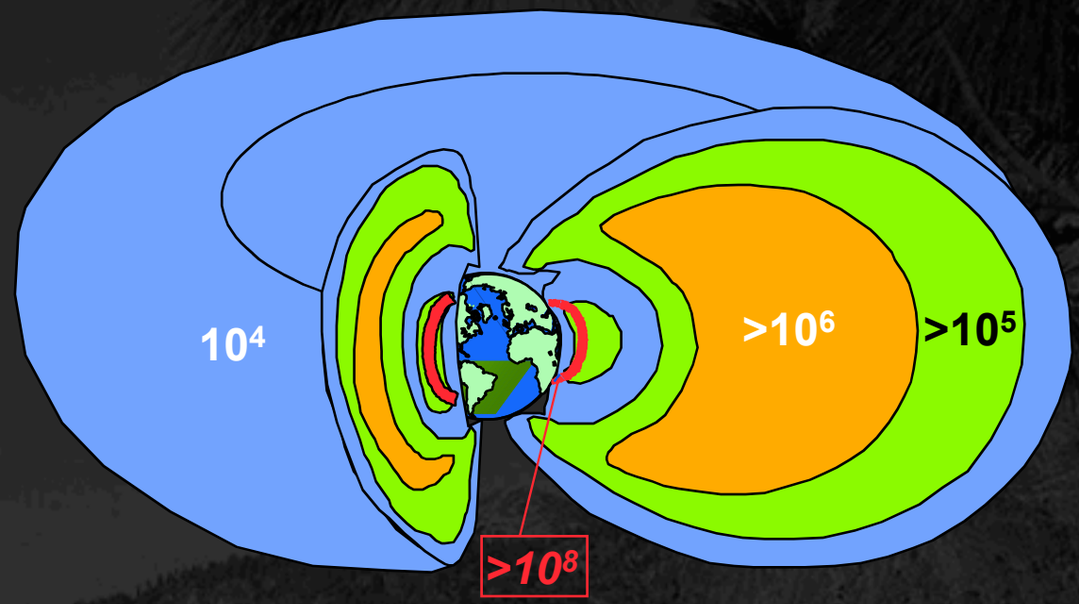
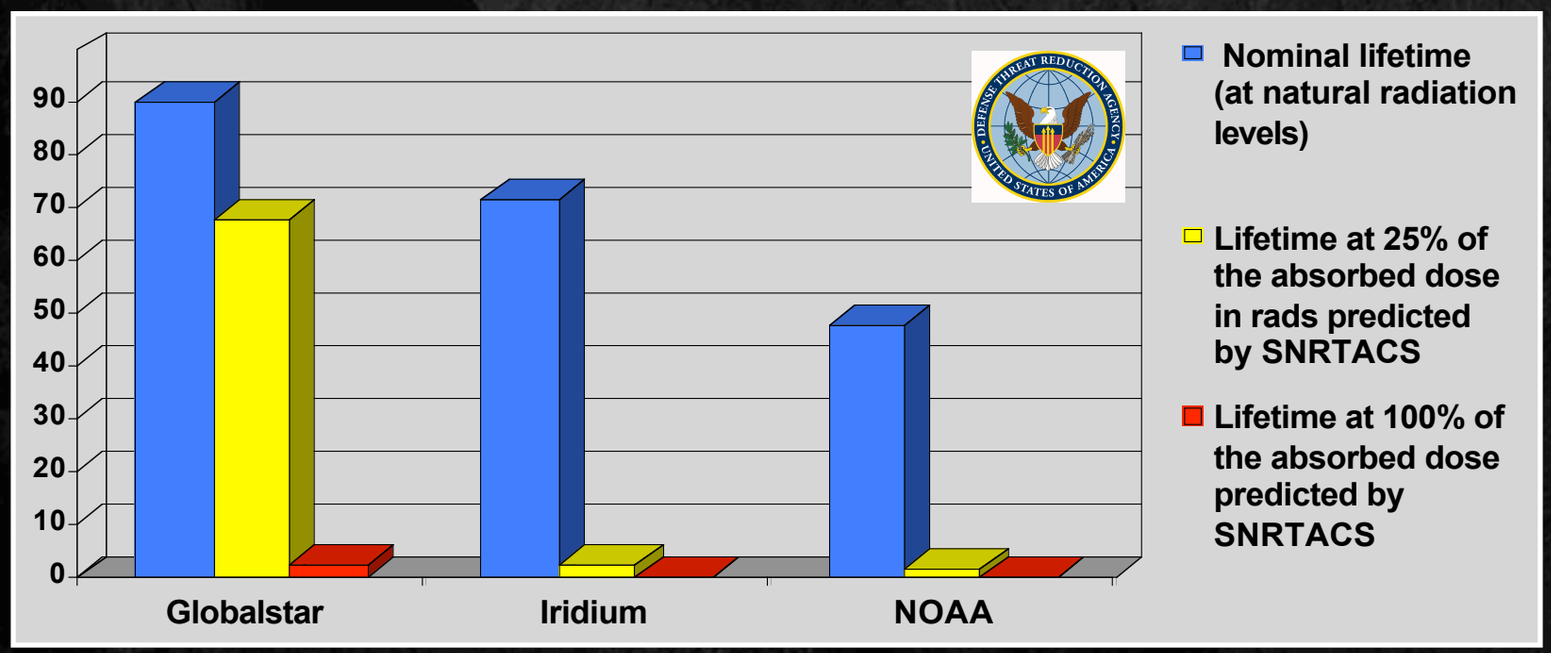
Practical Application



Natural and Enhanced Electron Population One Day After Burst Over Korea



Explosion-excited region



DTRA HALEOS Study
April 2001

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Physical Understanding

- Diffusion Rates:
  Radial, Pitch Angle, and Energy
- Adiabatic Effects:
  quantify the effects of the ring current
- Loss Rates:
  quantify the temporal & spatially dependence
- Stochastic Processes:
  when, where, how strong?

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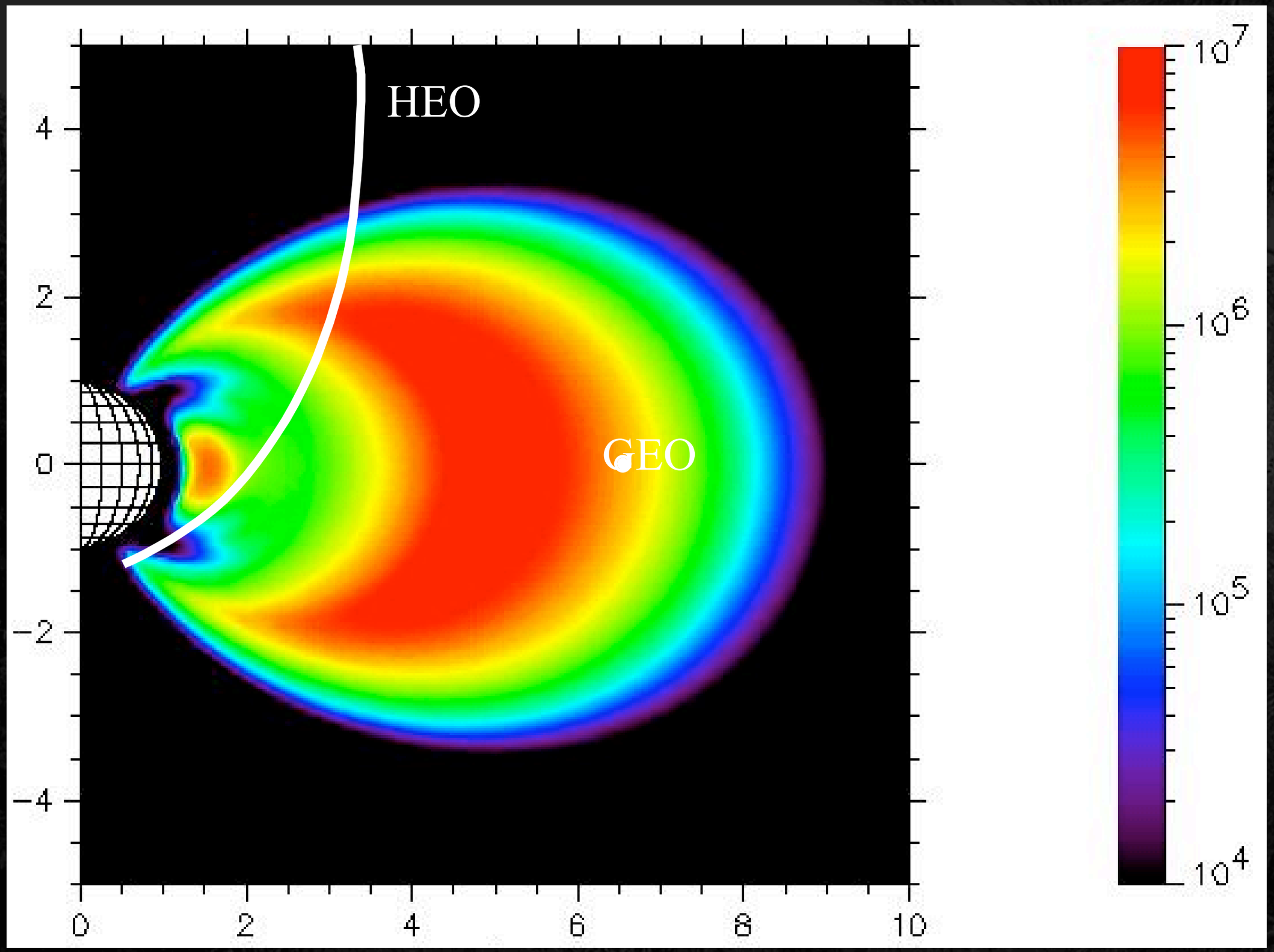

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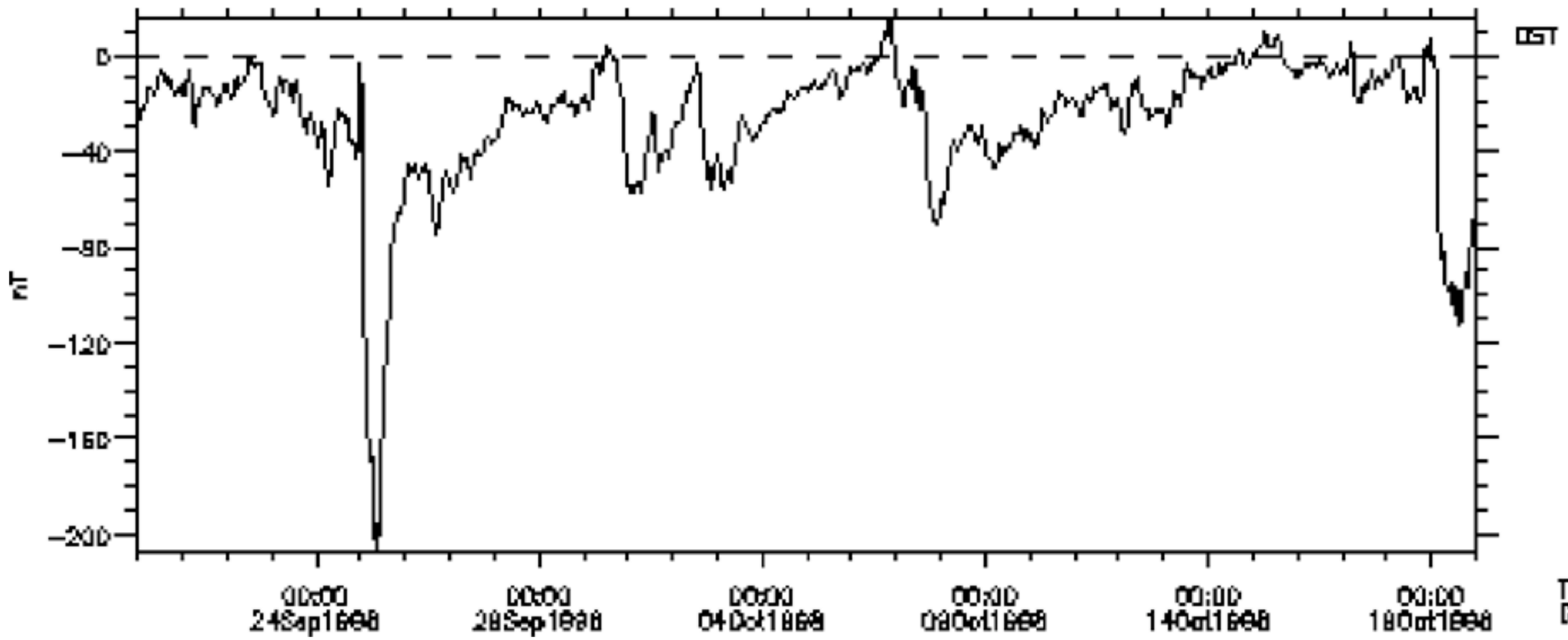
One Month of Storms



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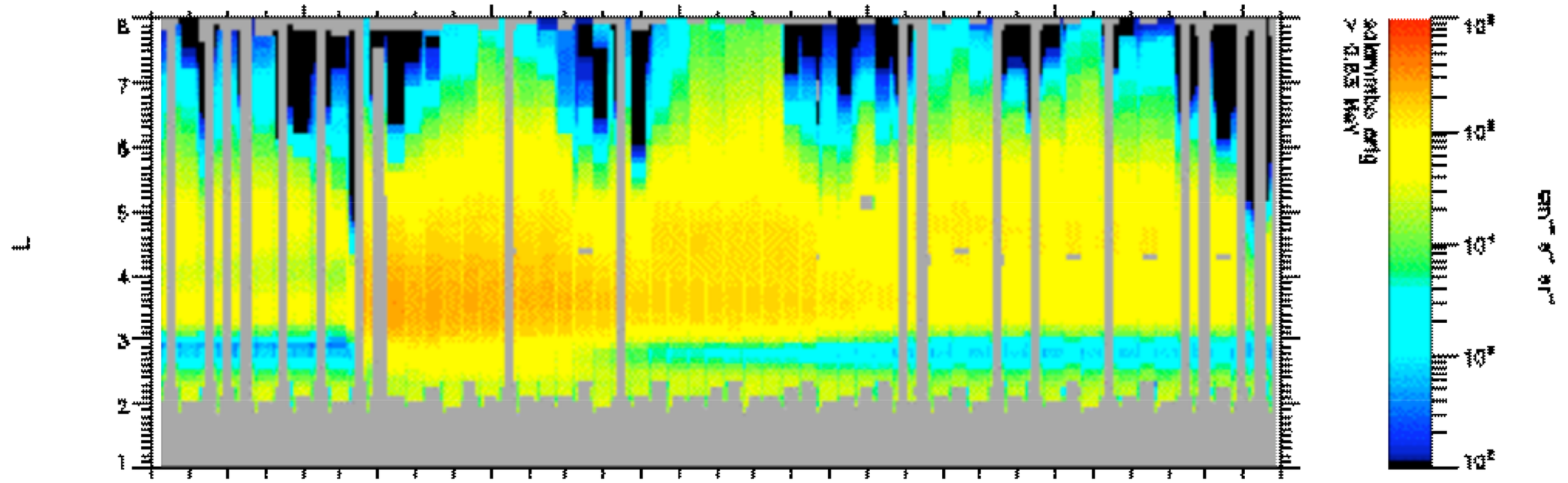
Measured Flux vs L



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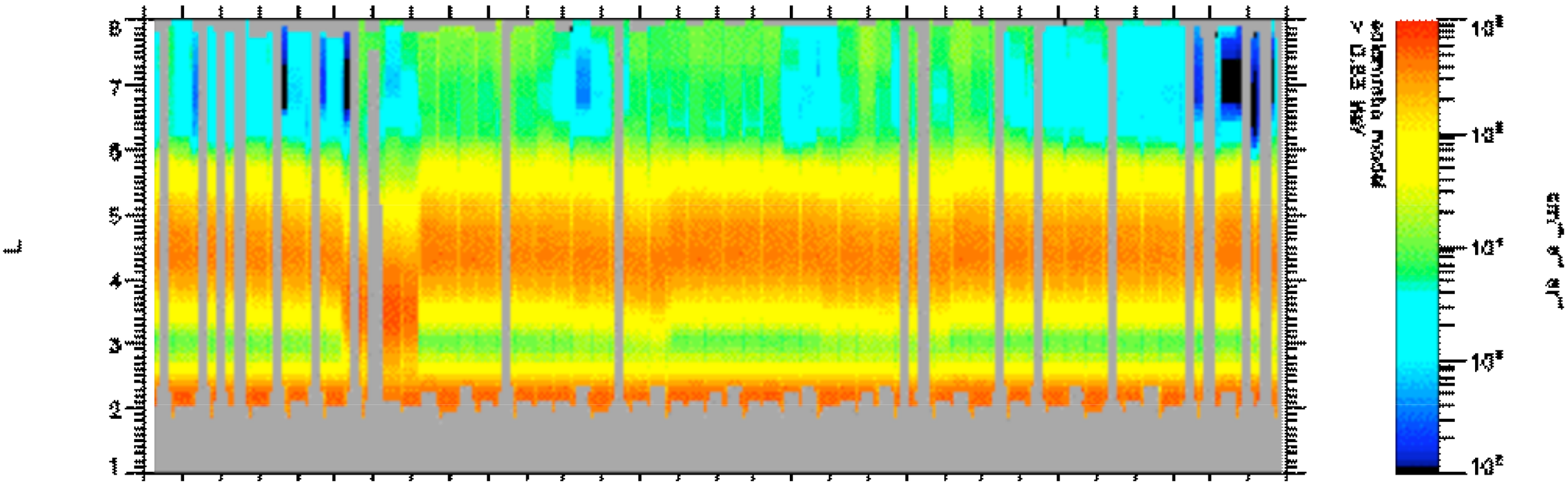
Model Flux vs L



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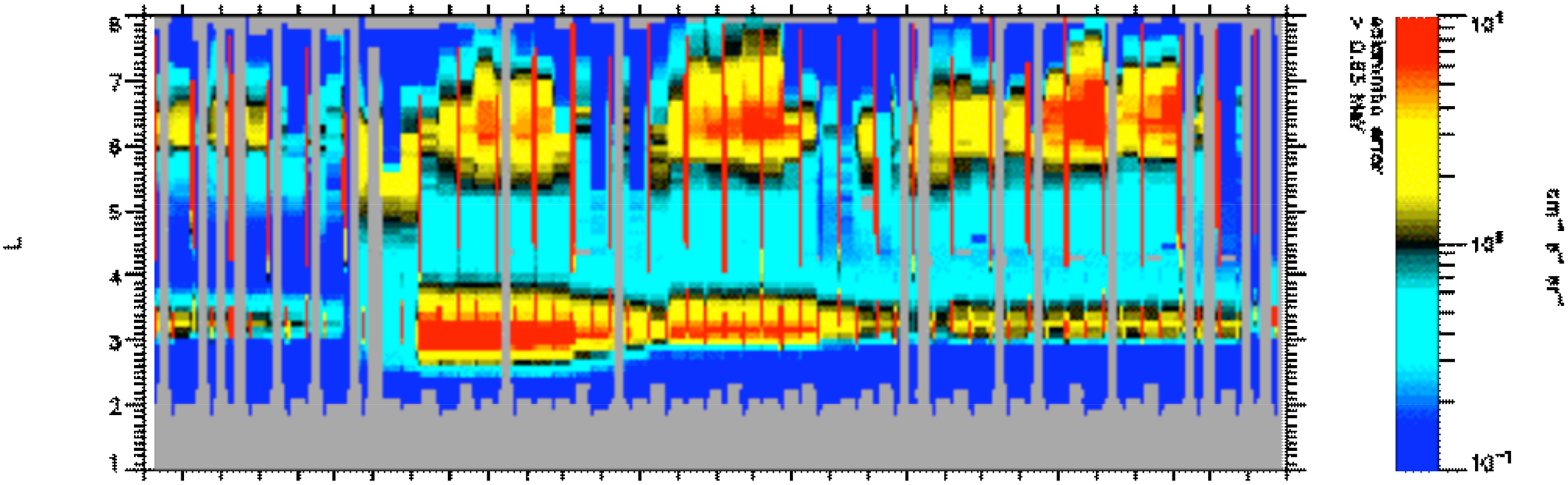
Ratio of Measured/Model



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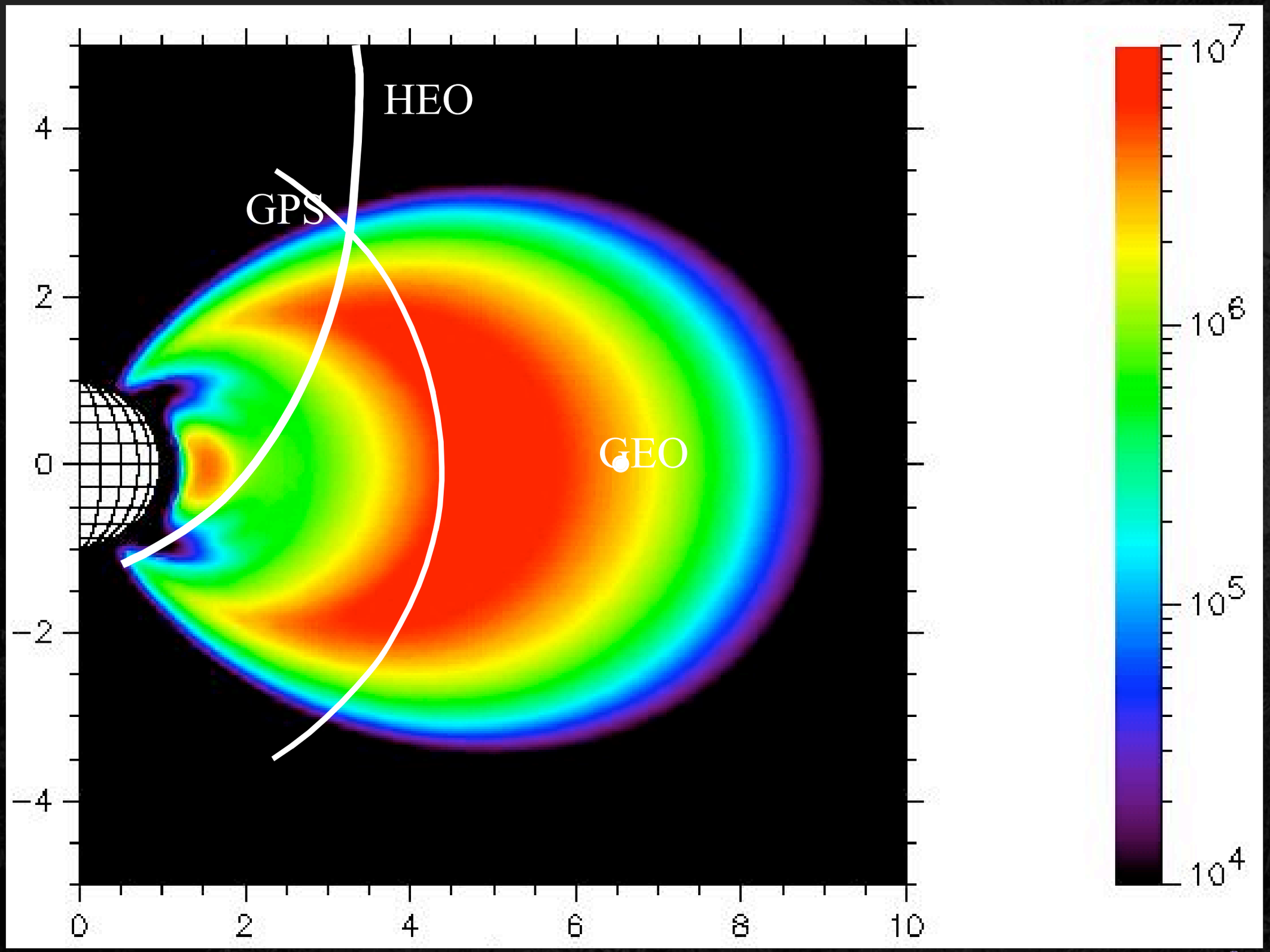

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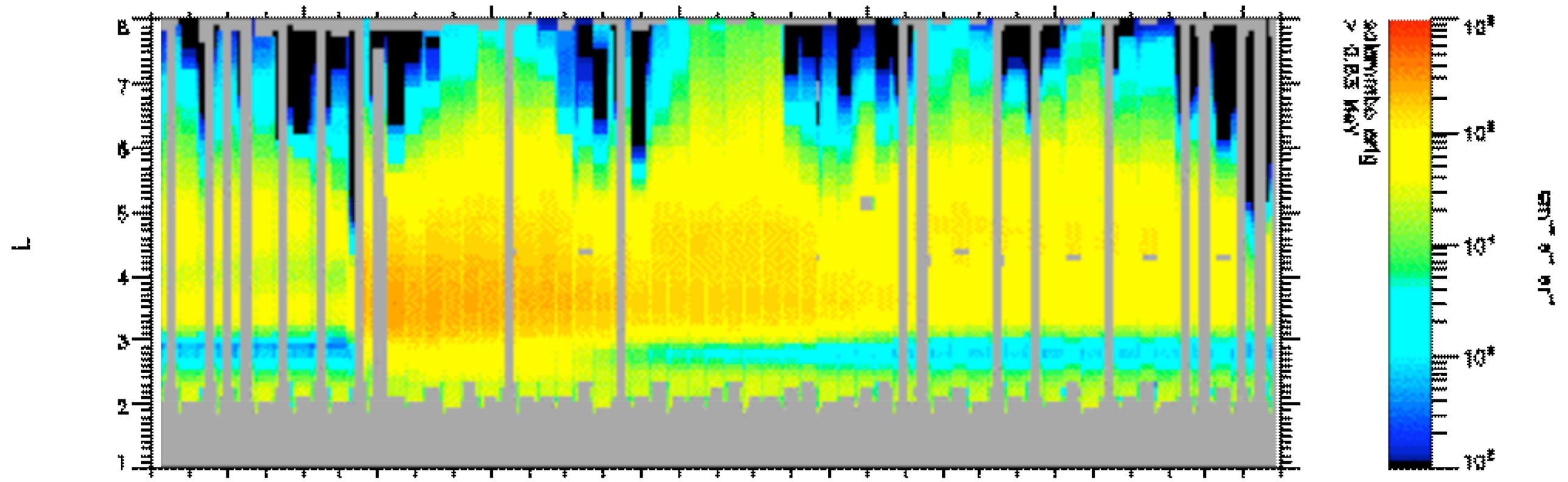
Measured Flux vs L



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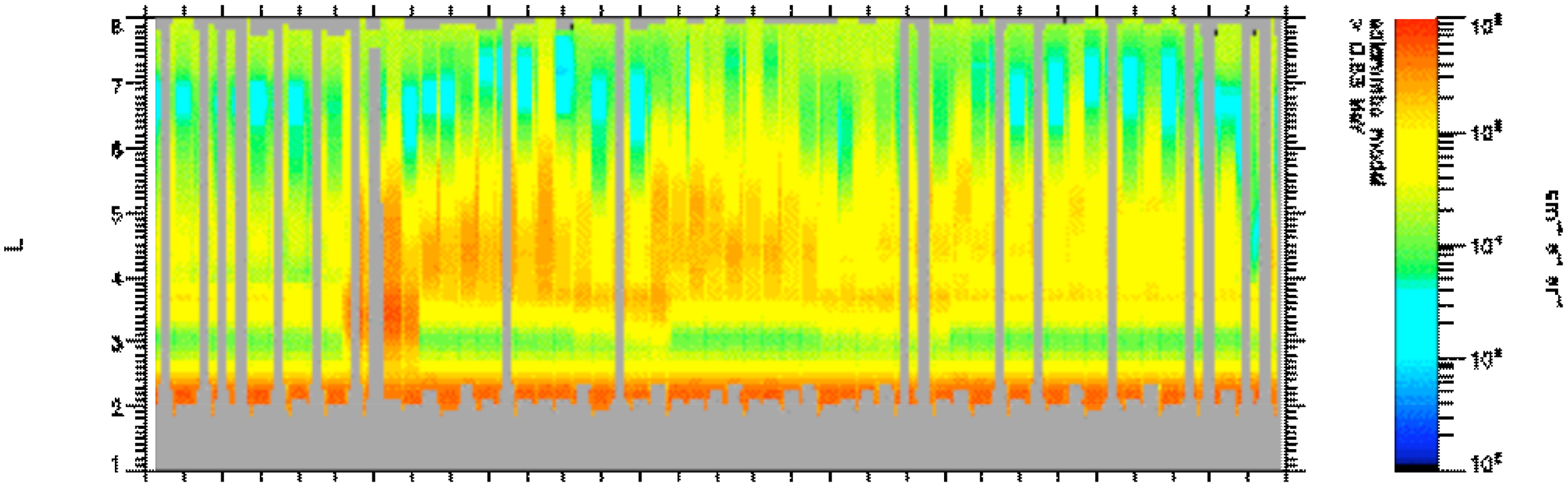
Model Flux vs L



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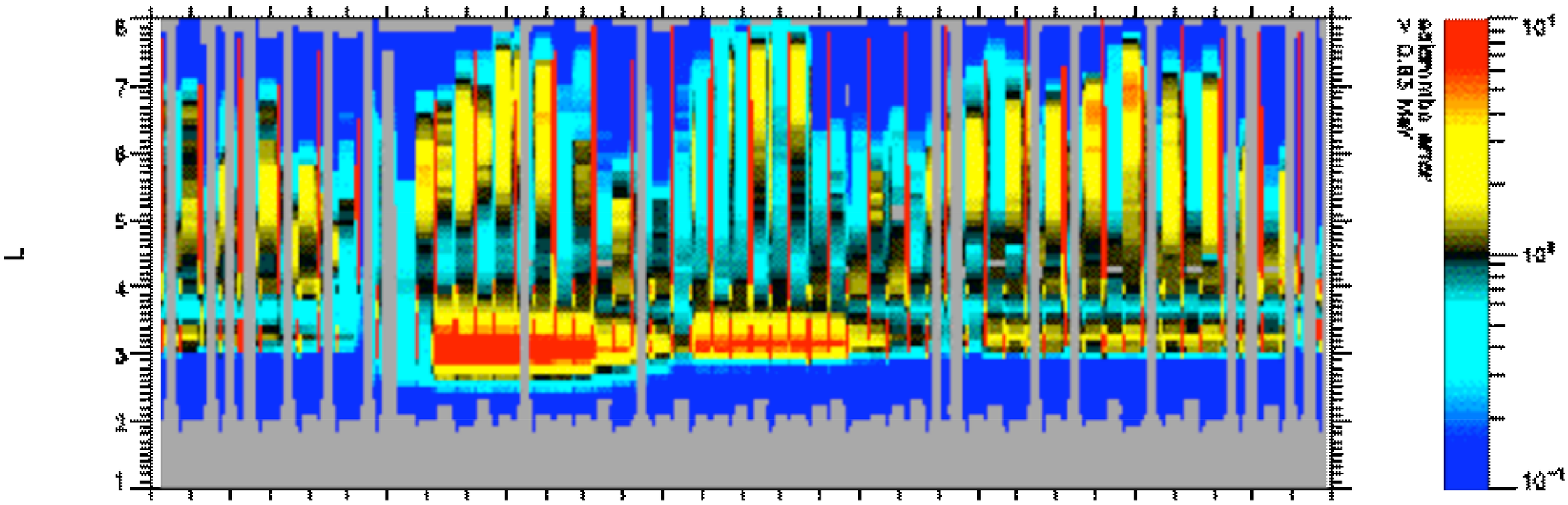
Ratio of Measured/Model



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Next Steps

- Allow adjustable, time dependent diffusion rates
- Calculate diffusion rates through storm consistent with observations

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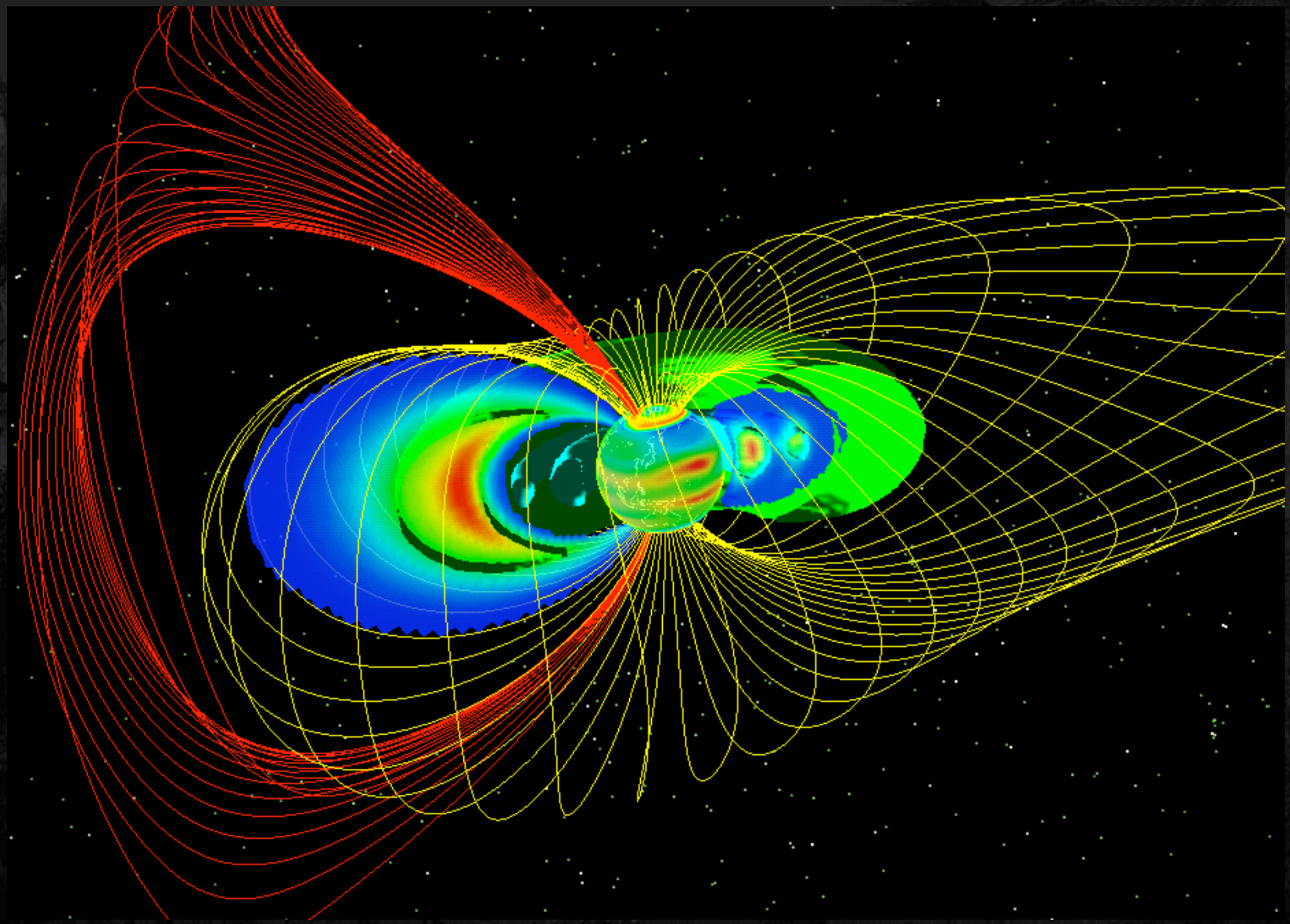
Solving Particles & Fields



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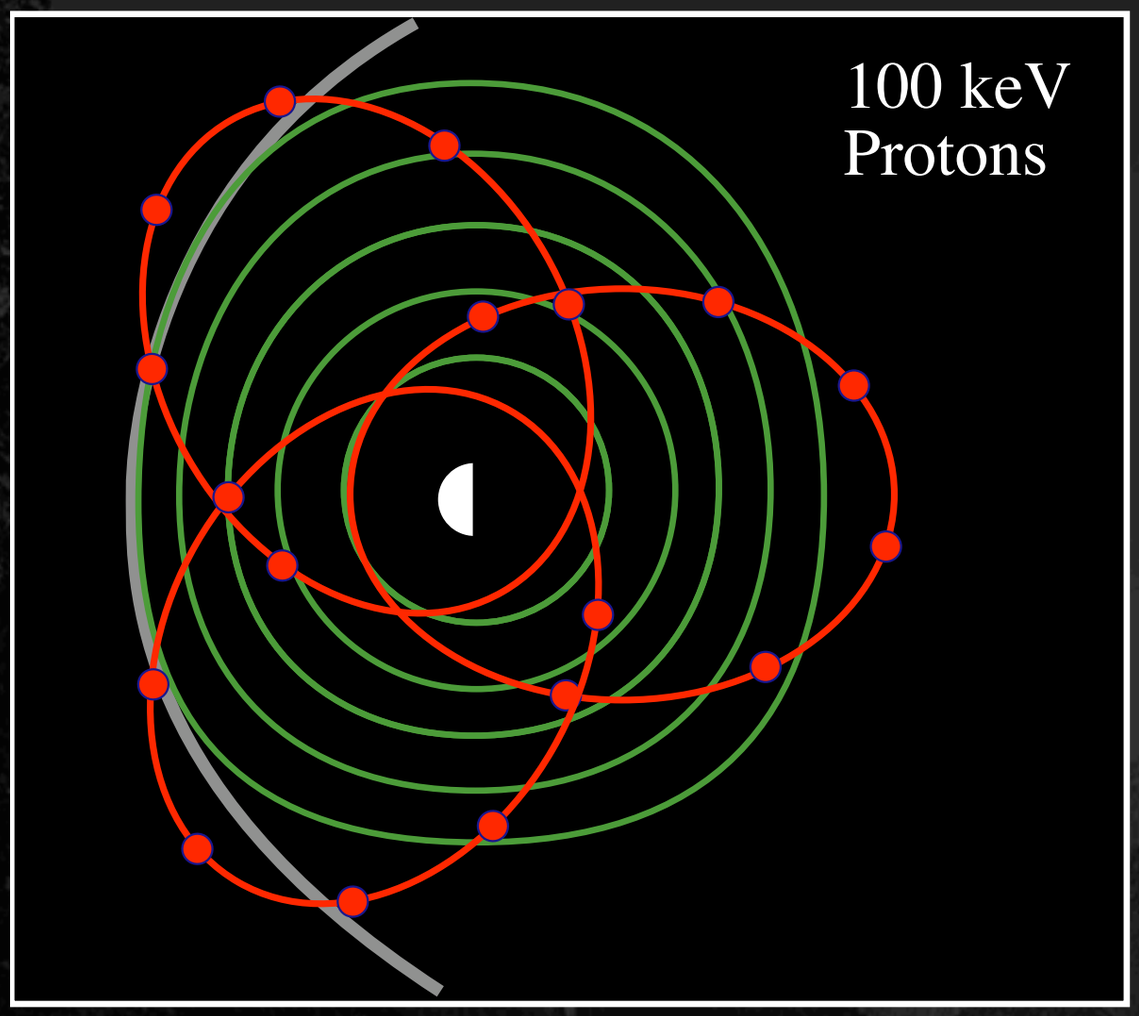
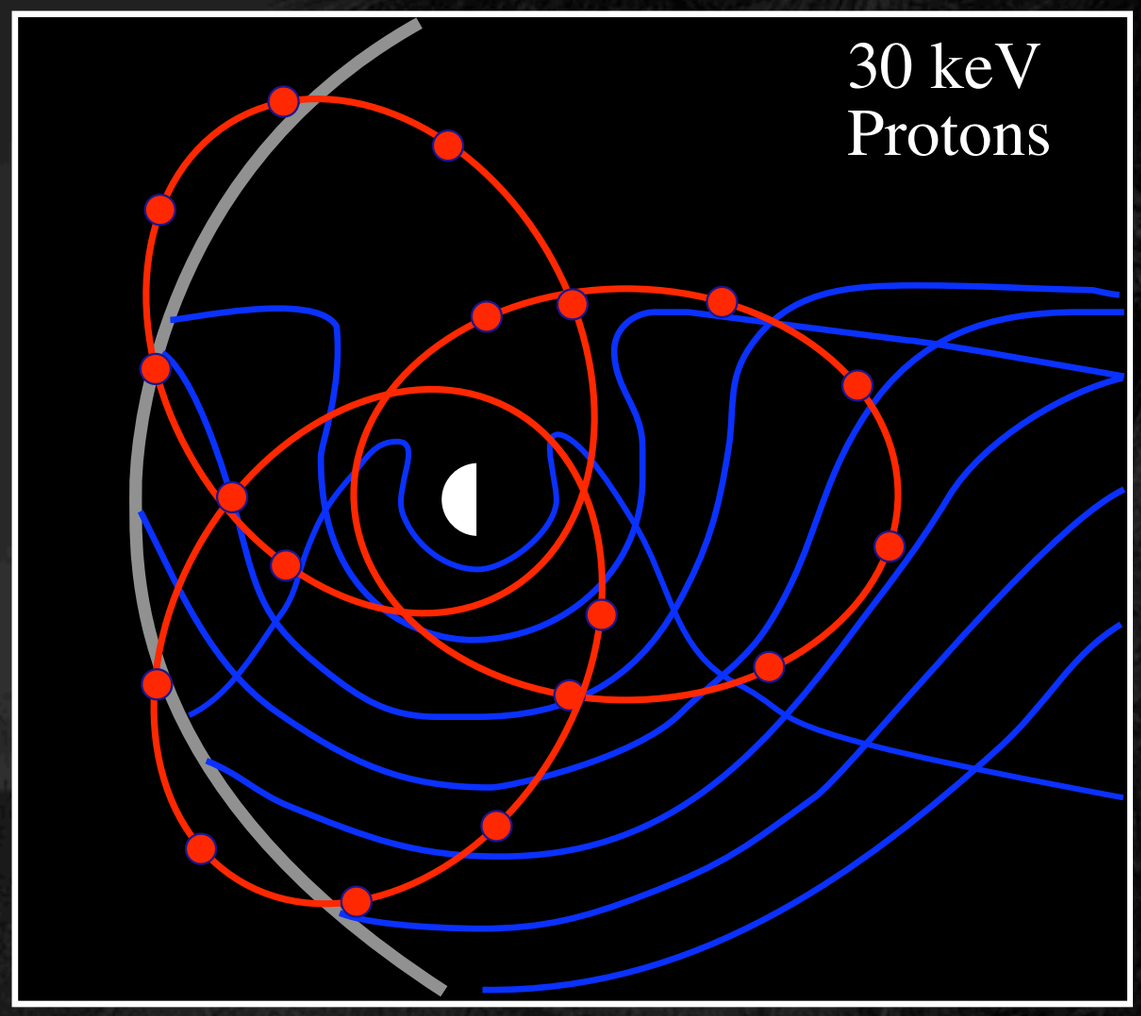
Using Liouville's Theorem





- Phase space density conserved along a path
- Drift shell splitting actually helps!
- A single field must be consistent
- Low energies remotely sense E as well as B

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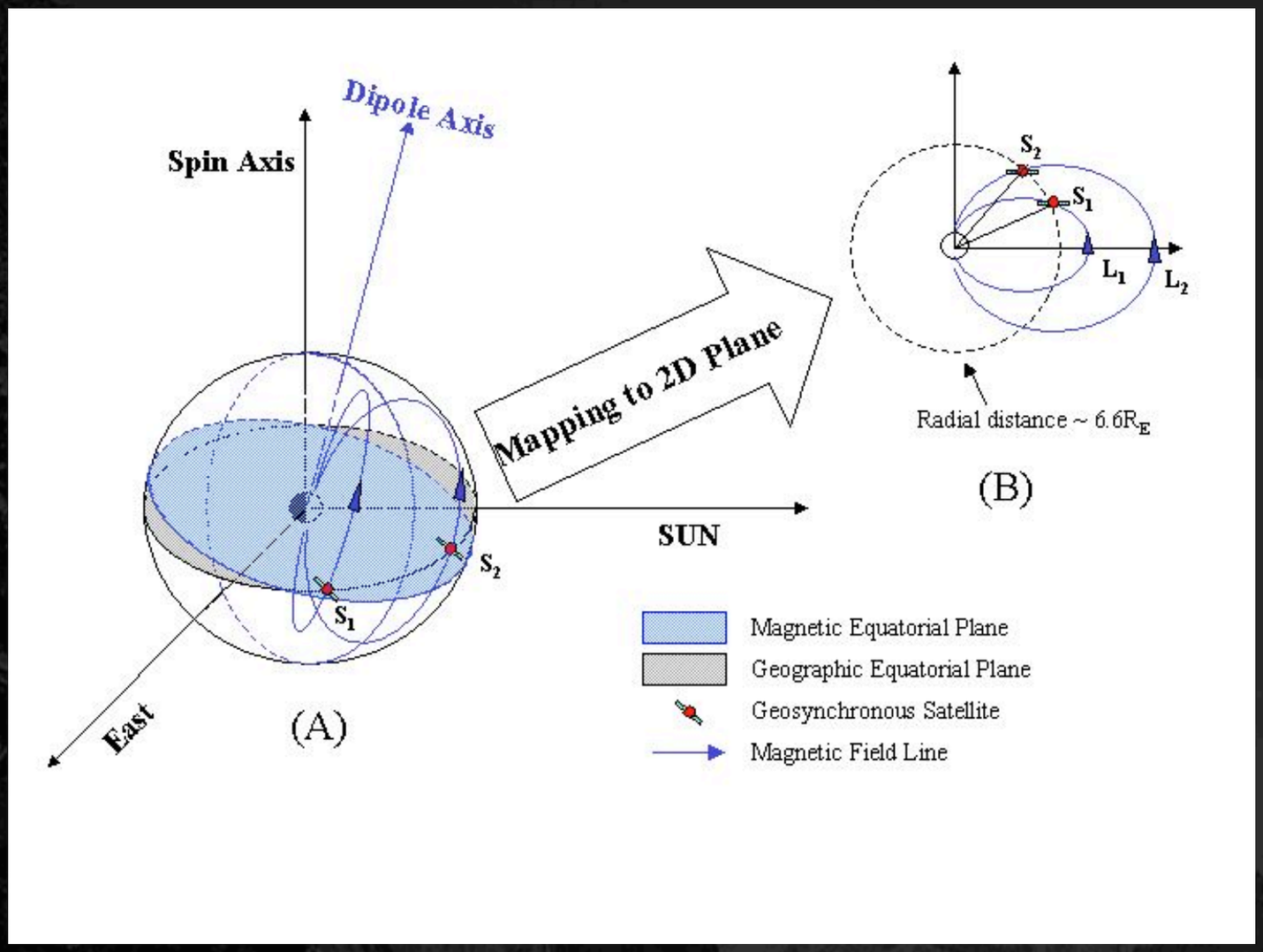
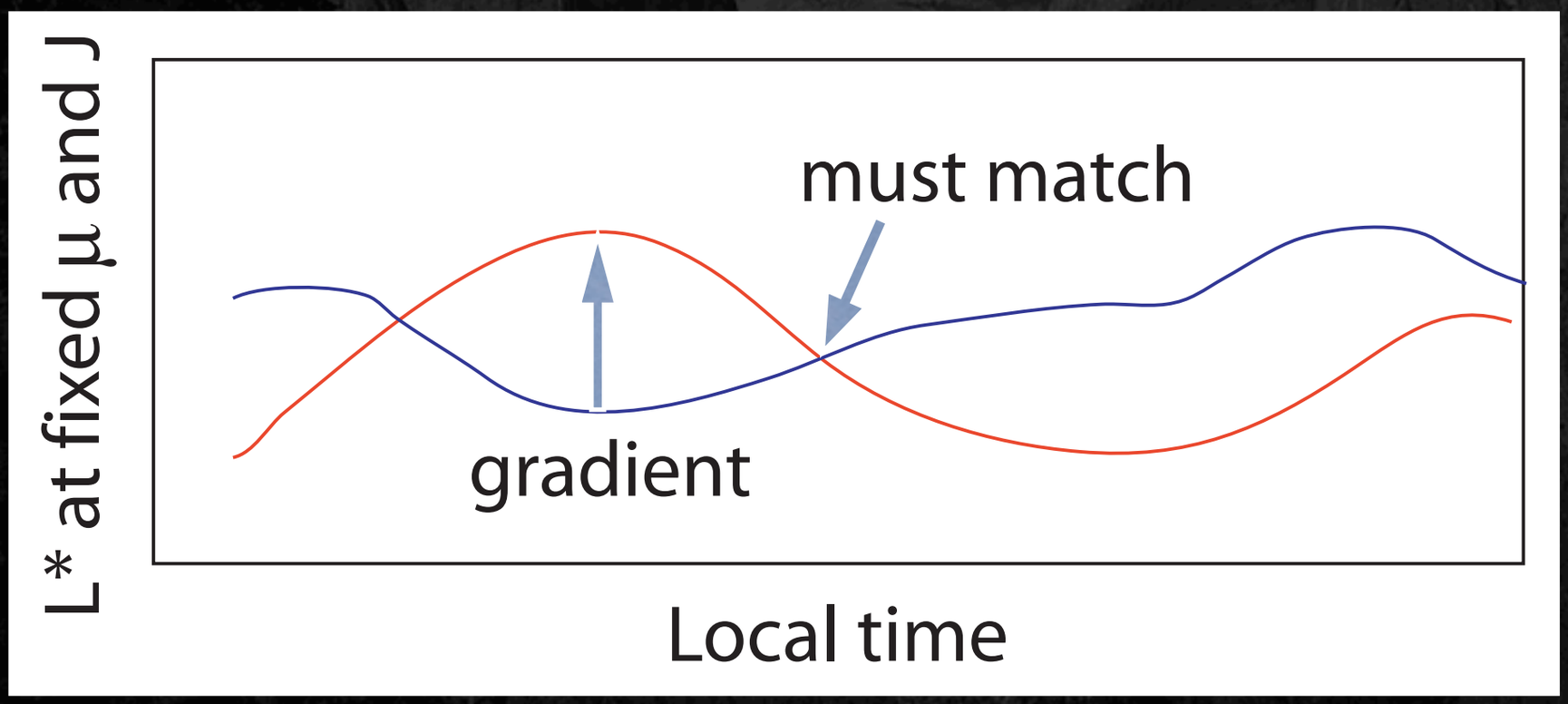


$\vec{B}$ from GOES
$\hat{B}$ from LANL

μ from B &
Energy Spectrum

J & L* from B model



PSD at fixed
μ, J, L*

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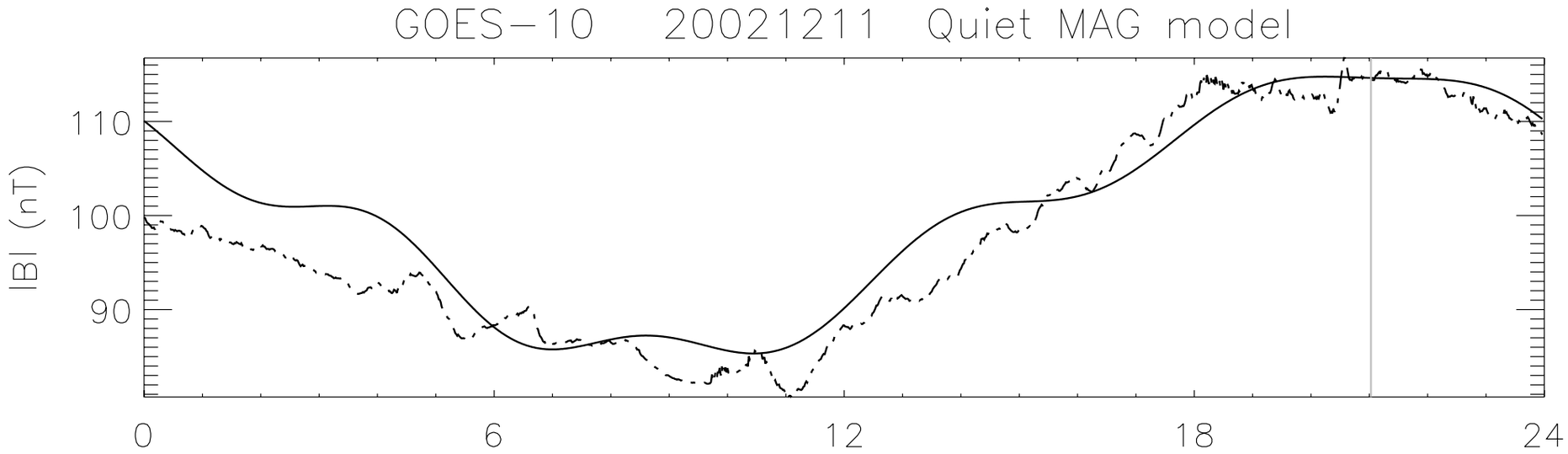
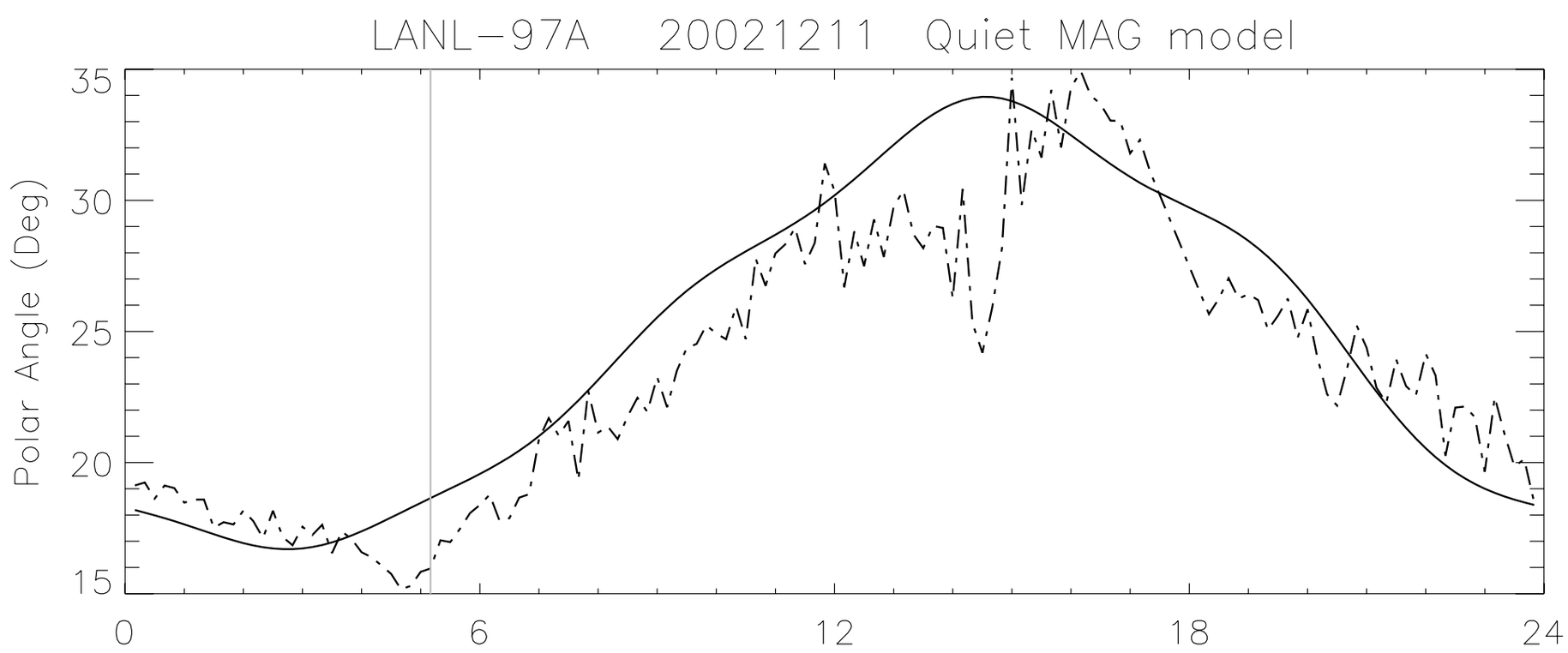
Application to Quiet Days

GOES 3-components, 2 s/c



LANL only θ and Φ, but 6 s/c



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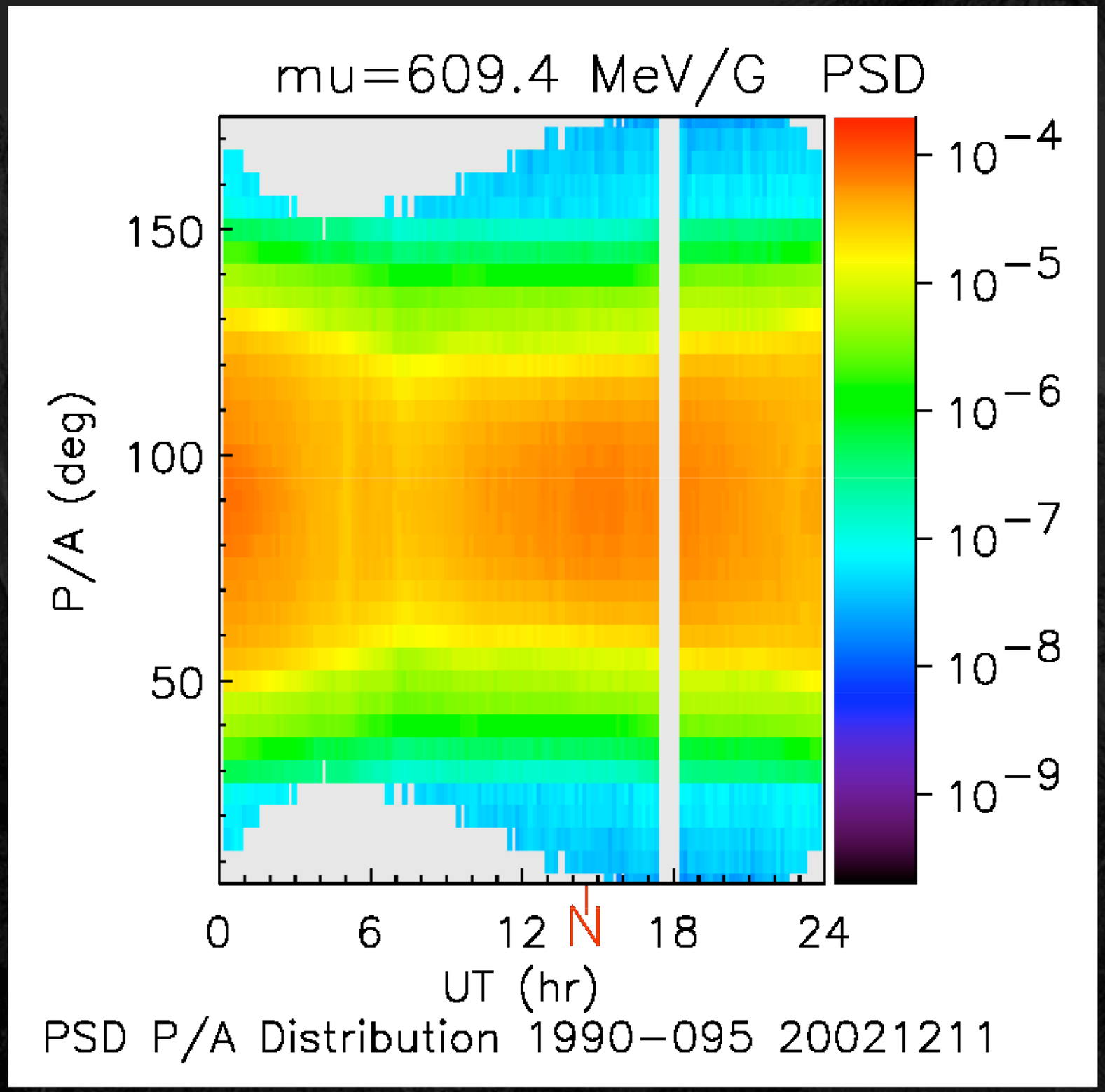
PSD vs Pitch Angle, fixed μ



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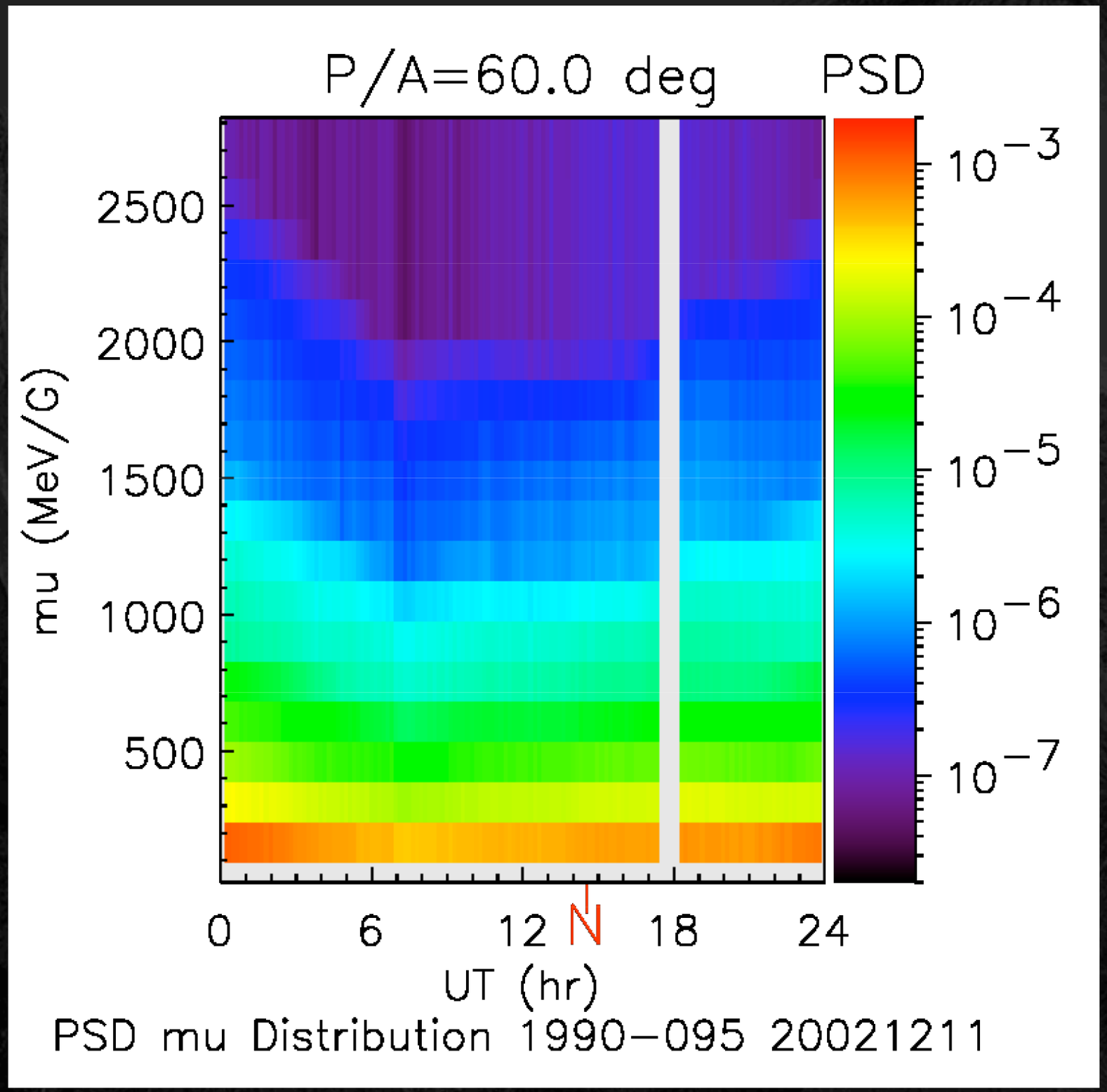
PSD vs μ, fixed Pitch Angle



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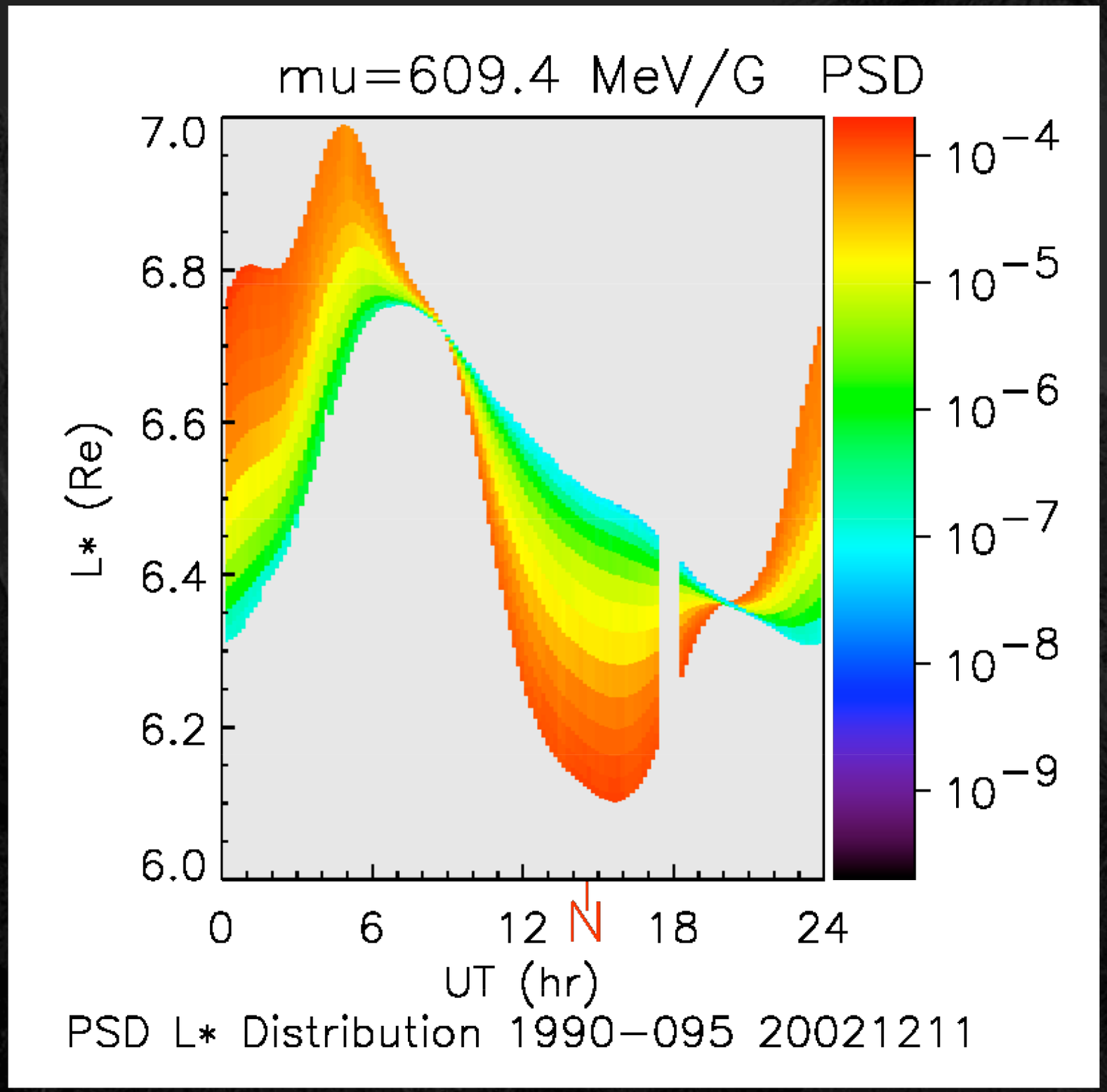
PSD vs L*, fixed μ, J



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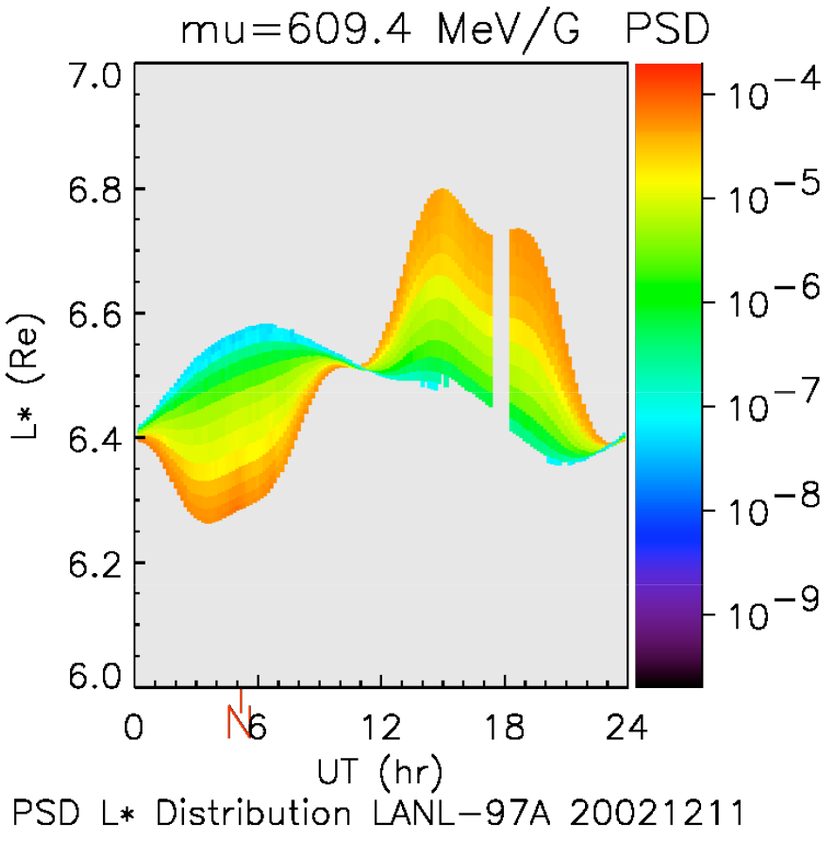
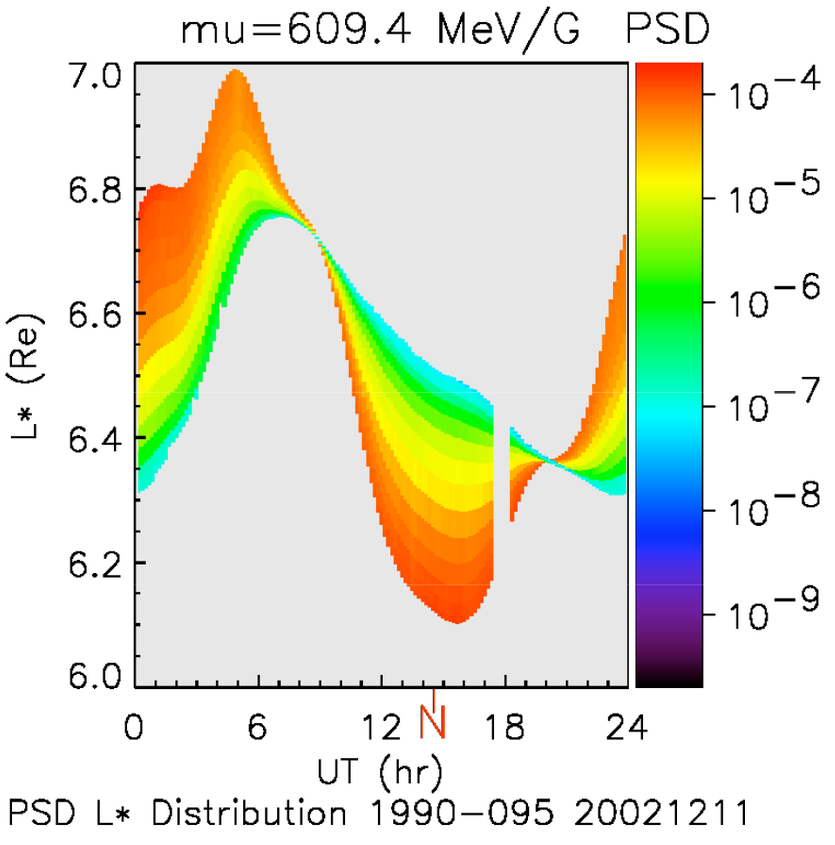
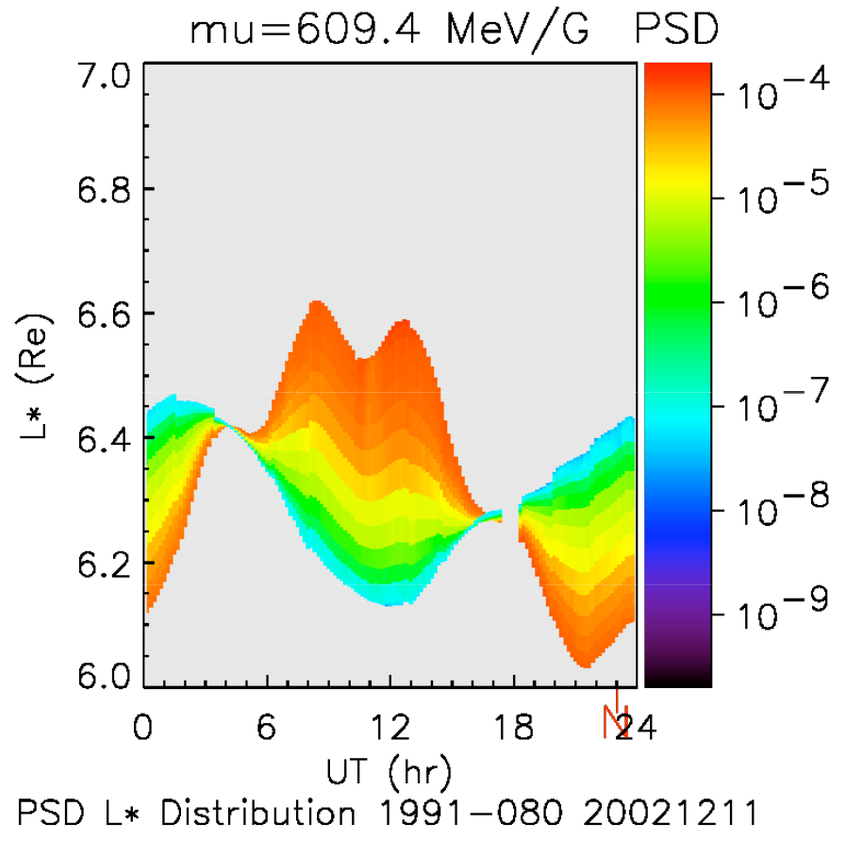
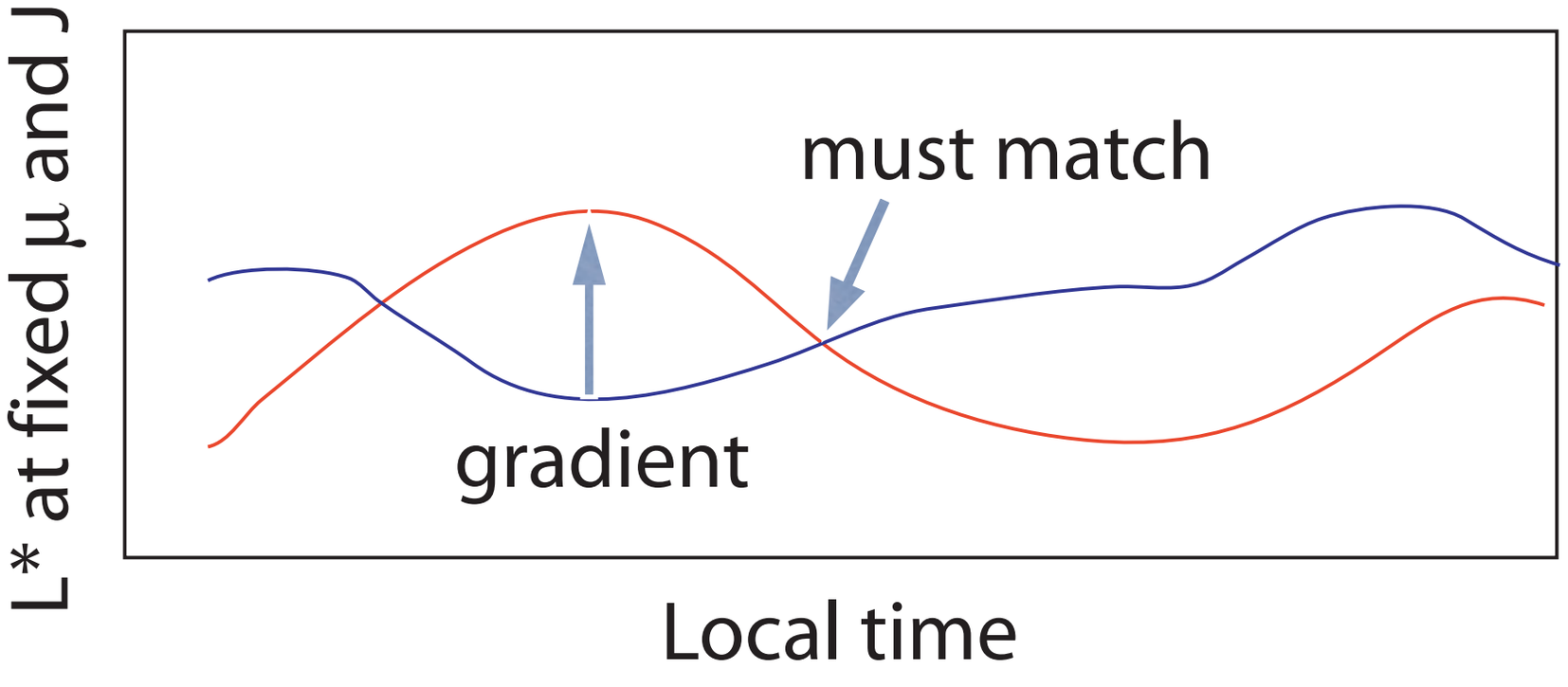
PSD vs L* for 3 Satellites









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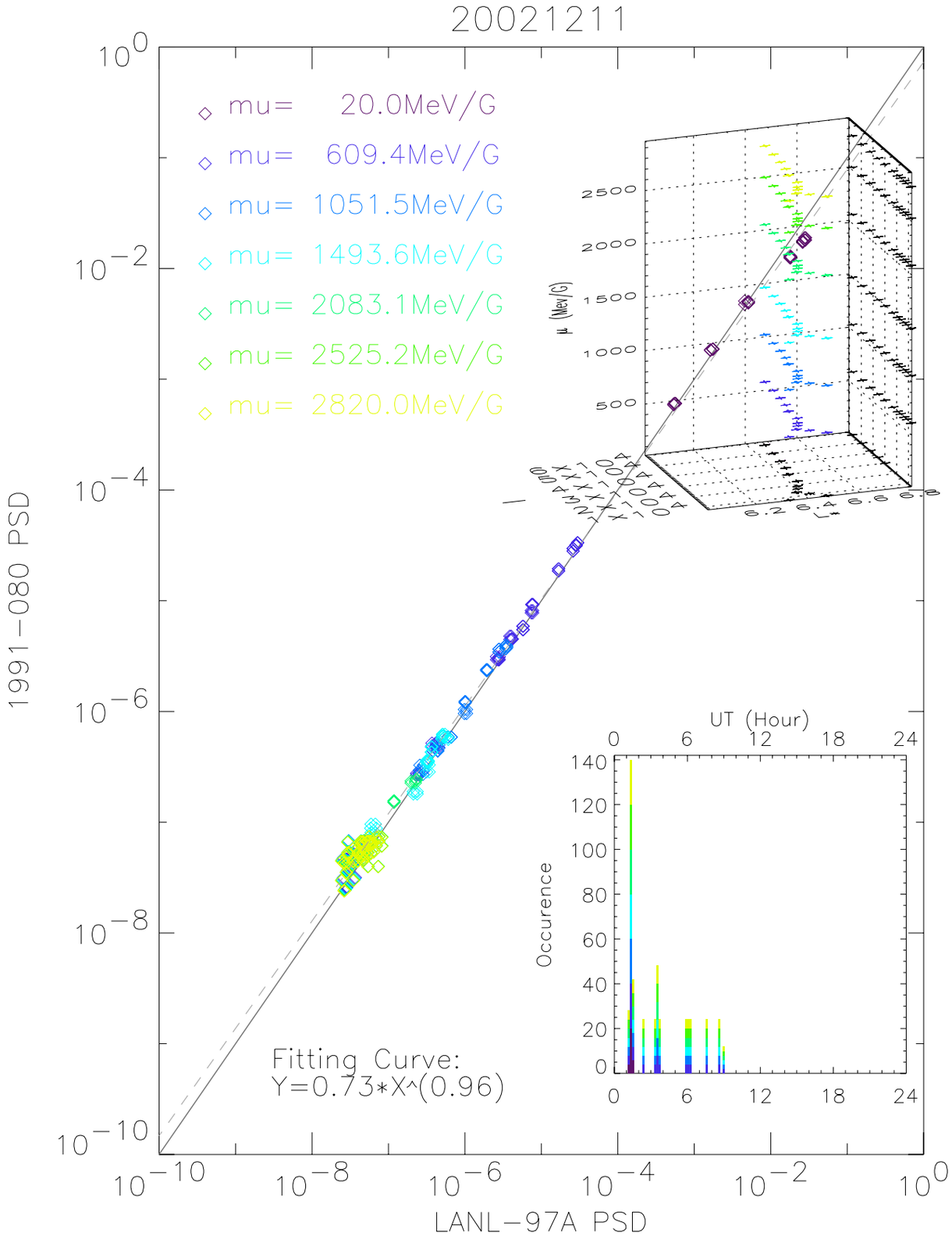
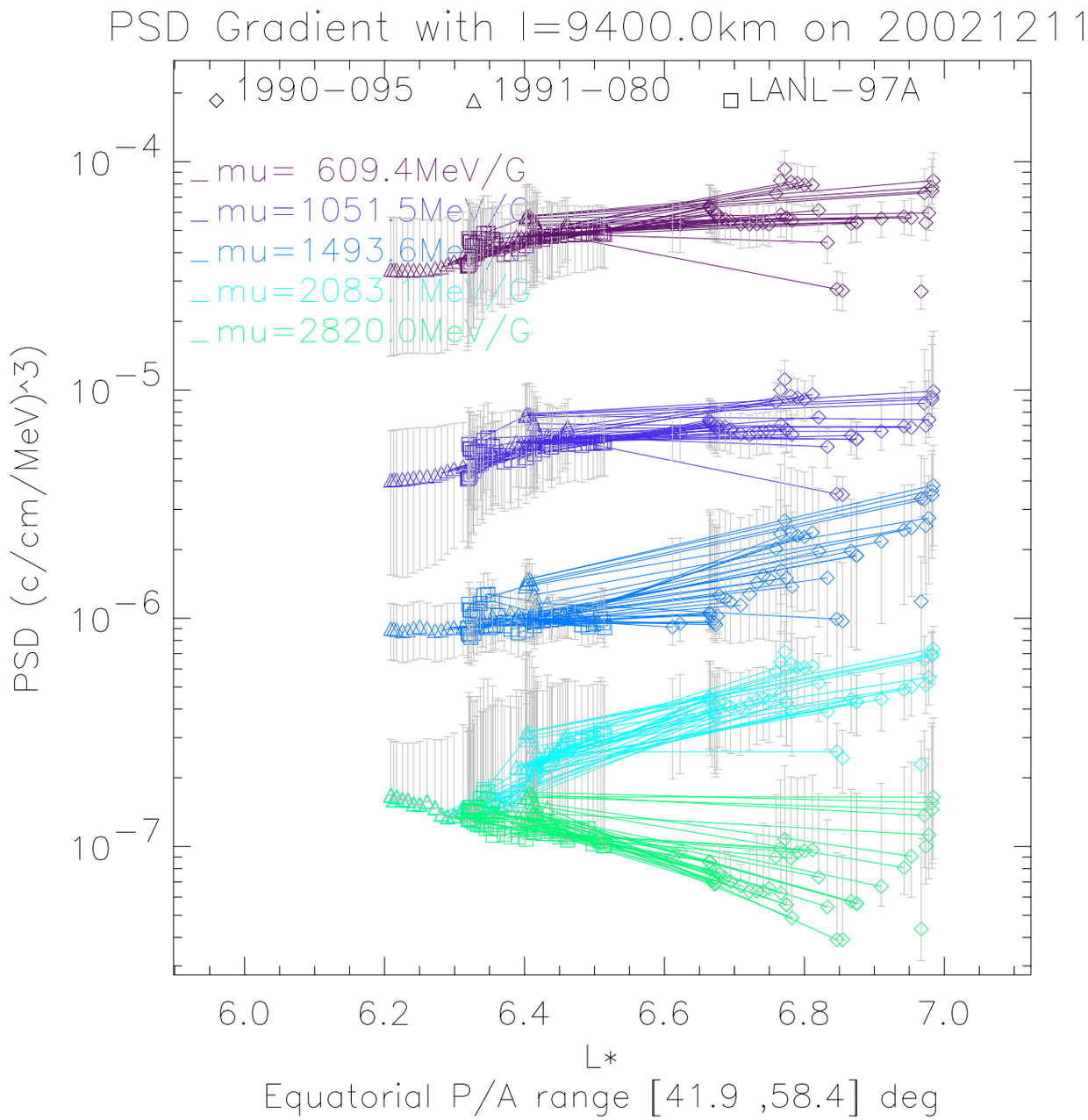
Matching & Gradients





Next Steps

- Allow adjustable, time dependent magnetic field model (e.g. T-01)
- Compare 'real Dst' with Dst determined from GOES & LANL

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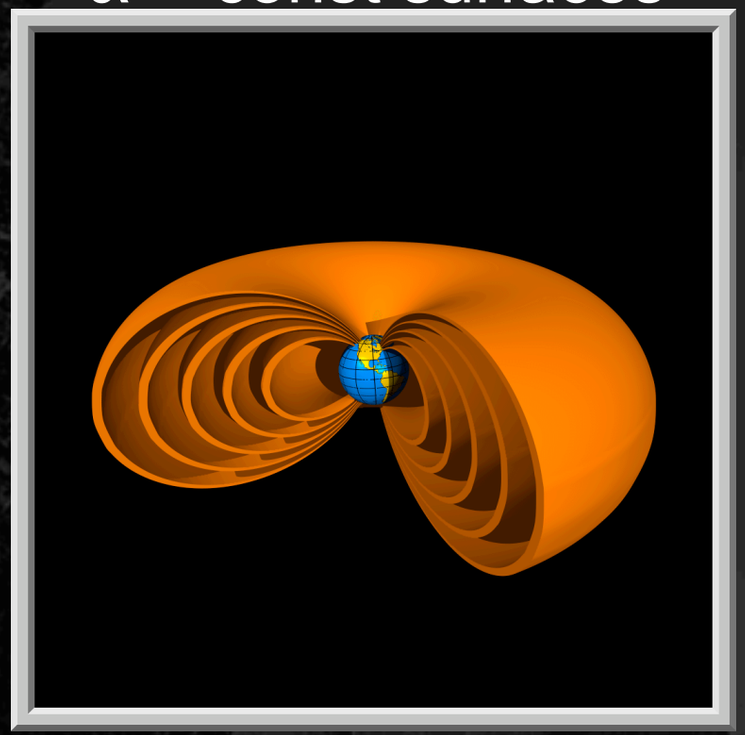
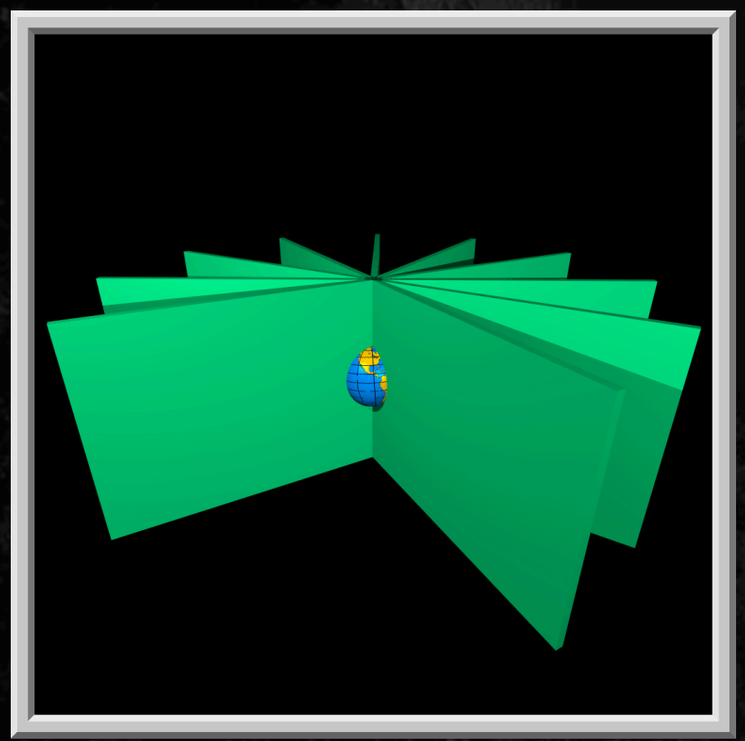
Deformable Magnetic Fields

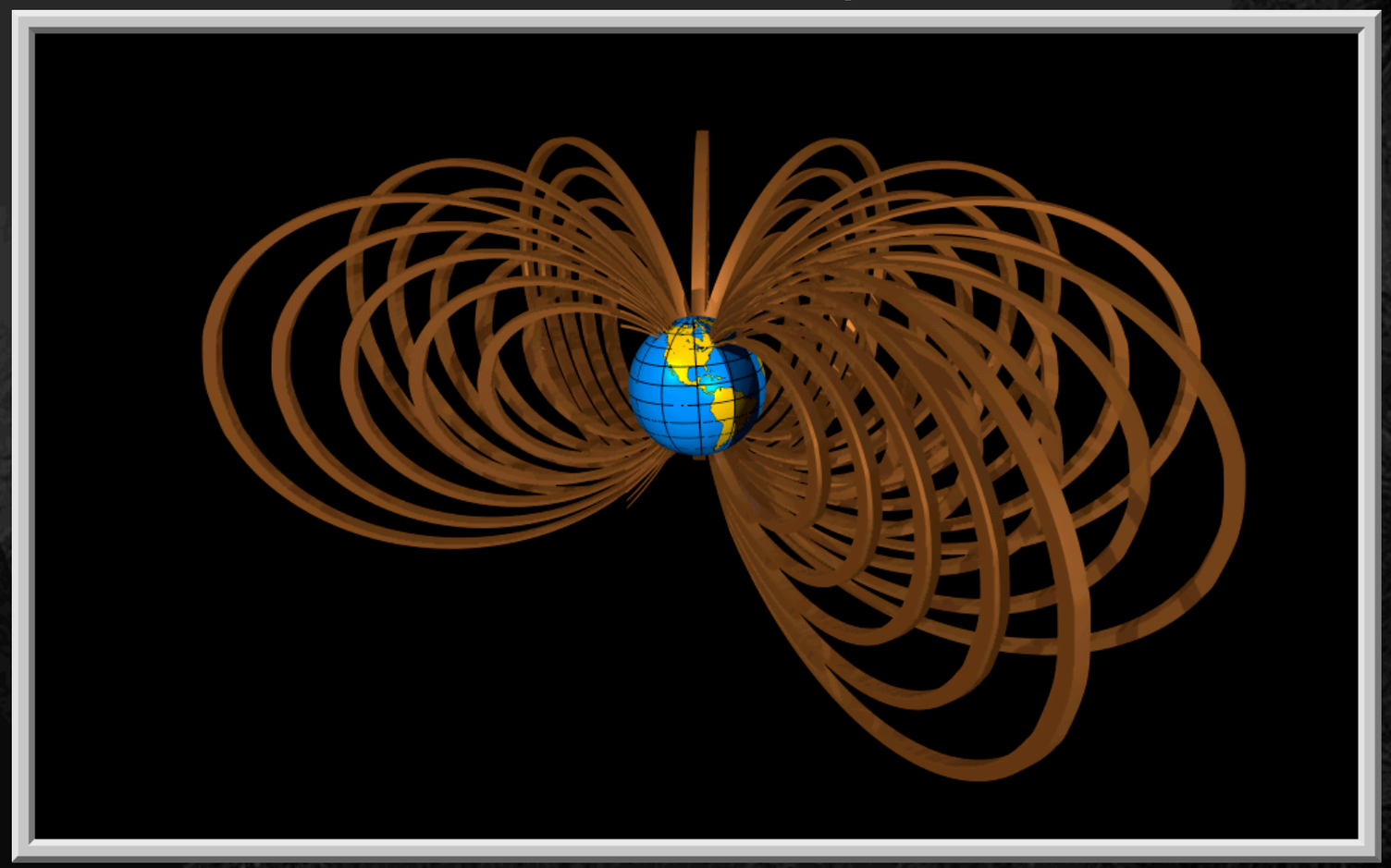
α = const surfaces



β = const surfaces



B = ∇α x ∇β



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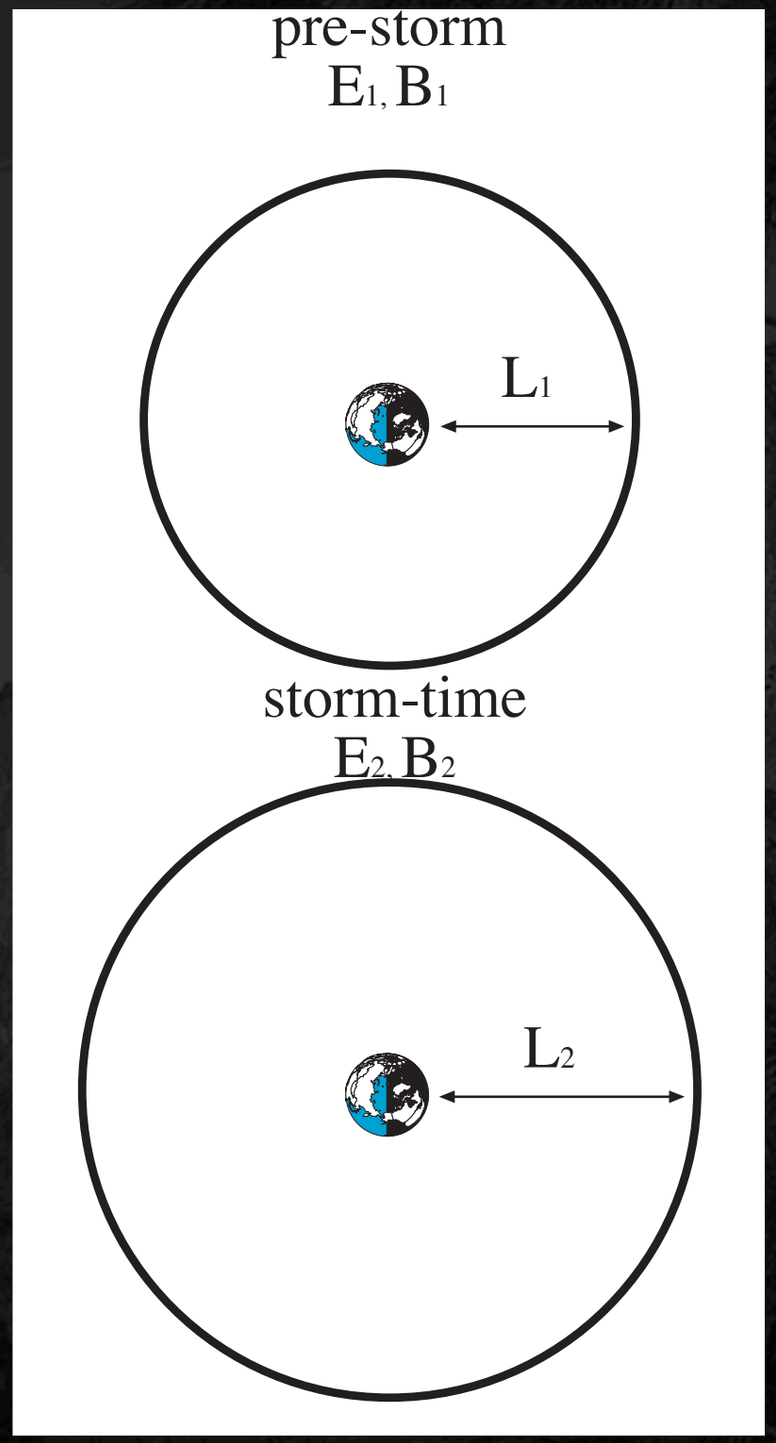
The ‘Dst’ Effect

- Must be consistent with particle motion

- Magnitude depends on Dst & Radial Gradient Spectral Slope

- Each new B model changes calculation of μ, J, L*



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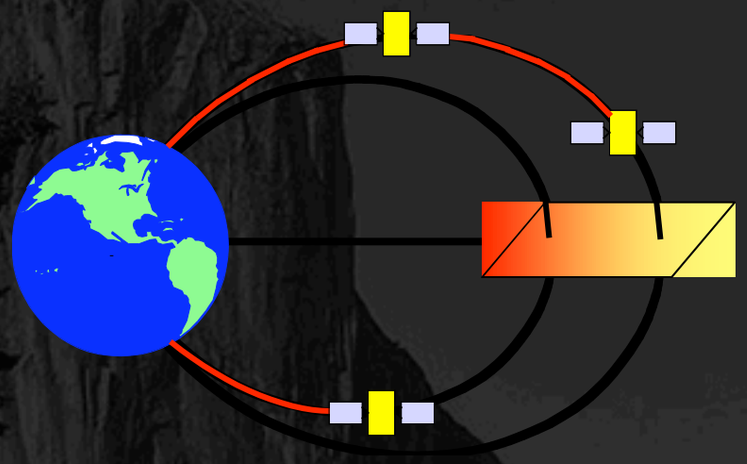
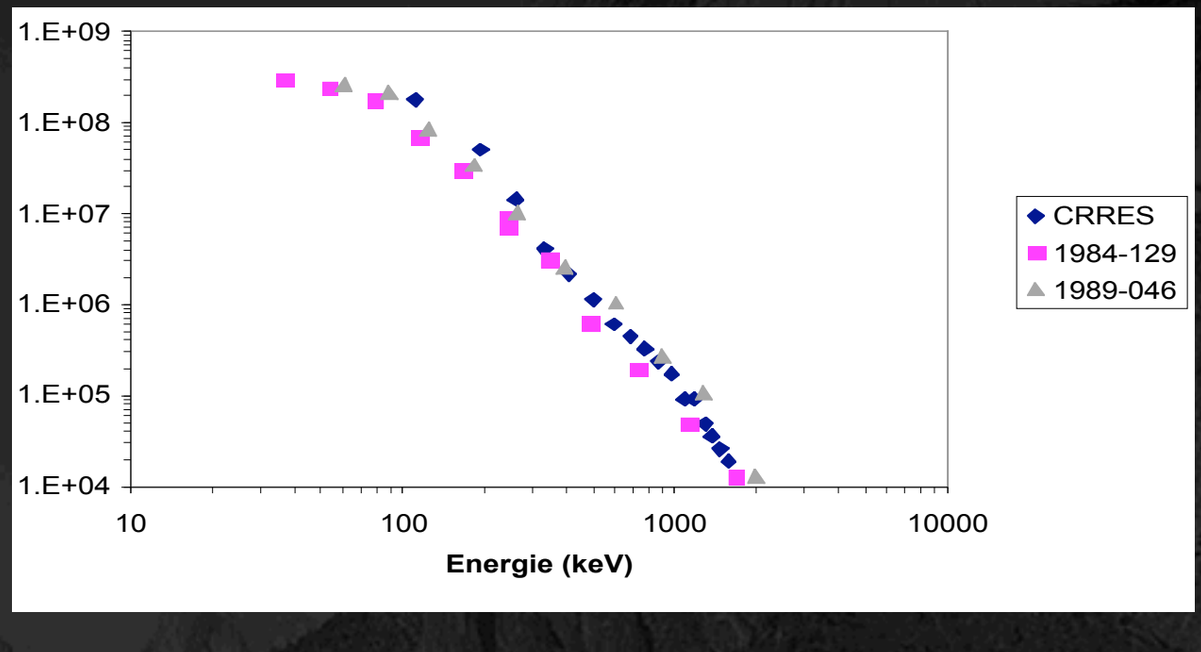
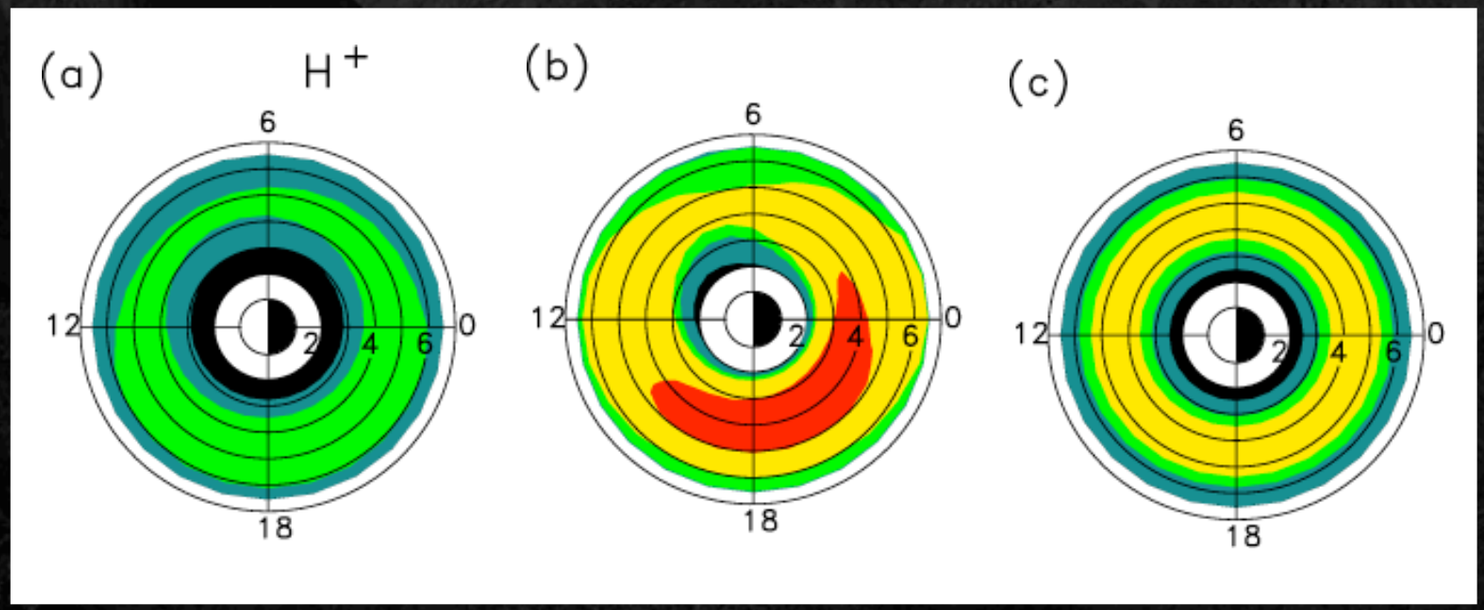
Other Challenges

- Satellite Data Intercalibration & other limitations





- Sophisticated but fast, highly-parallel codes



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